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CLIMATE PROFILE FOR THE McCALLUM *EMRIA* STUDY AREA

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Climatology Report 81-1

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Colorado Climate Center

31 March 1981

Mr. Bruce Van Haveren BVH 4/2/81
Bureau of Land Management
Bldg. 50
Denver Federal Center
Lakewood, CO 80225

Dear Bruce:

A final version of our report entitled Climate Profile for the McCallum EMRIA Study Area is attached. A total of 10 copies are being sent to you this day in two packages. Our second report required to complete the contract YA-553-CTO-77 will be submitted by April 15, 1981.

Sincerely,

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CLIMATE PROFILE FOR THE McCALLUM EMRIA STUDY AREA

by

Thomas B. McKee
Nolan J. Doesken
Freeman M. Smith
John D. Kleist

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Prepared for

Bureau of Land Management
Division of Special Studies
U.S. Department of Interior

Colorado Climate Center
Department of Atmospheric Science
Colorado State University
Fort Collins, Colorado
80523

March, 1981

Climatology Report No. 81-1

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Dr. Thomas B. McKee
State Climatologist

TBM:op
Enclosure

ACKNOWLEDGEMENTS

The authors would like to express thanks to the following people for their contributions to this report: to Odilia Panella and Janet Clark for dedicated typing, clerical, and grammatical assistance, to Mark Howes for an excellent job of drafting, to Katherine Corwin from the Department of Agronomy at Colorado State University for helpful comments and suggestions, and to Bruce Van Haveren of the Bureau of Land Management and Eugene Farmer of the U. S. Forest Service for sharing their knowledge and experience in reclamation work.

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CLIMATE PROFILE FOR THE McCALLUM EMRIA STUDY AREA

I. INTRODUCTION

Reclamation of mined lands is highly interdisciplinary, drawing on the knowledge and expertise from a wide variety of technical fields ranging from geology to agronomy. Climate is one of the important inputs which plays a major role in reclamation.

Several aspects of climate influence reclamation activities. The degree to which climate affects reclamation is determined by the climate itself. However, the degree to which reclamation activities are undertaken in accord with the climate depends more on the amount of information available and the form in which the information is made available.

Climatic conditions in the North Park area of Colorado provide definite limitations. This climate profile is intended to give a description of the climate near the McCallum site, place it in perspective, review available climatic data, illustrate the important aspects of climate for reclamation, and provide recommendations for reclamation activities.

II. RECOMMENDATIONS

The climate profile for the McCallum Study Area leads to the following recommendations.

- The annual and seasonal precipitation contour maps for Colorado (prepared by the U.S. Weather Bureau in the 1960's and disseminated by the Colorado Water Conservation Board) should not be used as the standard reference for North Park precipitation information.

- Precipitation observations should be continued at the McCallum Study Area to establish, with certainty, the local precipitation climate. Collection of other data on site, such as daily maximum and minimum temperatures, wind speed and direction, and humidity would also be desirable.

- Lack of precipitation will be the factor most limiting to revegetation efforts.

    --The reclamation strategy should include plans and resources for multiple seeding attempts since the establishment of vegetation is likely to fail frequently. If this is unacceptable, the application of supplemental water should be considered.

    --Mulching, additional topsoil, and special shaping and contouring of the land surface should be considered for increasing soil moisture capacity and storage capability.

- Fall seeding (for spring germination) is preferred to take full advantage of spring precipitation for plant establishment. Dates for fall seeding should be based on seed germination requirements. Efforts should be made to delay seeding to avoid warm periods which could cause premature germination.

- The combination of extreme cold, high winds, very dry air, warm daytime temperatures and lack of snowcover will cause winterkill for some young plants. Increasing the surface roughness and enhancing snow accumulation will minimize the winterkill problem.

- High wind conditions will occur several times each winter. Snow fences may be required to protect ridges subject to wind erosion and desiccation.

- Considerably more extensive plant species sensitivity data should be acquired to better define plant-climate couplings and to place vegetation selection for reclamation on a sounder scientific basis.

III. McCALLUM CLIMATE IN PERSPECTIVE

A. Geographical Factors

The McCallum Study Area is located in north central Colorado at a latitude of 40° 44' N and a longitude of 106° 7' W. The site has an interior continental location situated in a very broad, high-elevation mountain valley east of the Continental Divide.

The broad valley surrounding the McCallum Study Area is known as North Park, a wide, open expanse of land surrounded by higher mountains. Four major ranges enclose the park: the Park Range to the west, the Rabbit Ears Range to the south, the Medicine Bow Mountains to the east, and the Independence Mountains to the north. The Continental Divide runs southward from Wyoming along the crest of the Park Range and turns eastward across the Rabbit Ears Range before turning back to the south near Cameron Pass at the southeast end of North Park.

The park is approximately 25 miles wide and is drained by the North Platte River and several major tributaries. The North Platte flows northward through a gap between the Independence and the Medicine Bow Mountains into Wyoming. Elevations within the park are generally between 7,900 and 8,500 feet above sea level while the surrounding mountains rise to above 10,000 feet in most directions. The city of Walden lies in the center of North Park and is the only population center in the area.

The McCallum Study Area is situated 8 miles east of Walden and only about 5 miles from the base of the Medicine Bow Mountains at the eastern edge of North Park. The terrain slopes gently downward to the east and north toward the Canadian River Valley. The Canadian River flows to the north northwest right at the foot of the Medicine Bow range.

B. Temperature

The large-scale geographical features have a pronounced effect on the climate of North Park and the McCallum site. Because of its mid-latitude, continental location, seasonal variations in temperature are well pronounced. Monthly average maximum, minimum, and mean temperatures along with daily temperature extremes for Walden are shown in Figure 1. Walden experiences a large seasonal range in temperature ranging from a mean January temperature of 15°F to a monthly mean temperature of 59°F in July. Day to night (diurnal) temperature variations are also large because of the high elevation of the area and the interior mountain-valley location. During the winter months the diurnal temperature range averages 25 degrees F, but this increases to nearly 40 degrees in midsummer to early fall.

Extremely cold nighttime temperatures occur with regularity. Temperatures of -20°F and colder occur every year at Walden. The coldest temperatures usually occur in January and February. Figure 2 shows the average number of days each year when temperatures are at or below certain levels. Temperature of 0°F and below have occurred in all months except May through August. Even in midsummer, below freezing temperatures can occur. The average freeze-free period for Walden, shown in Table 1, is only 33 days with July and early August being the least likely period for experiencing sub-freezing temperatures. However, daytime temperatures stay well above freezing throughout the summer season, and daily maximum temperatures of 32°F and below occur on an average of 75 days per year. Due to its high elevation location, extremely warm temperatures are very rare. The all time highest

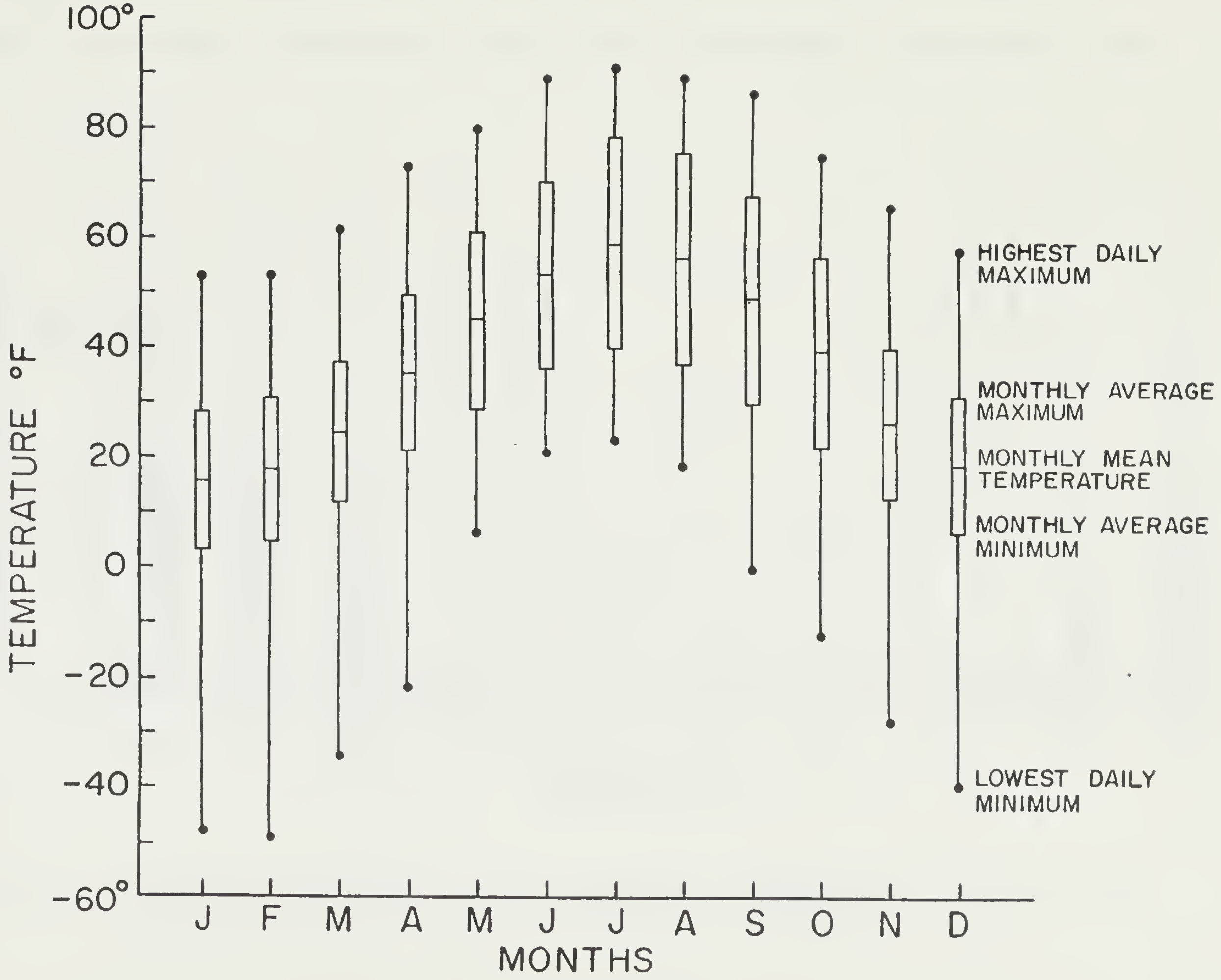


Figure 1. Monthly average maximum, minimum and mean temperatures and daily extremes for Walden, Colorado, 1938-1979.

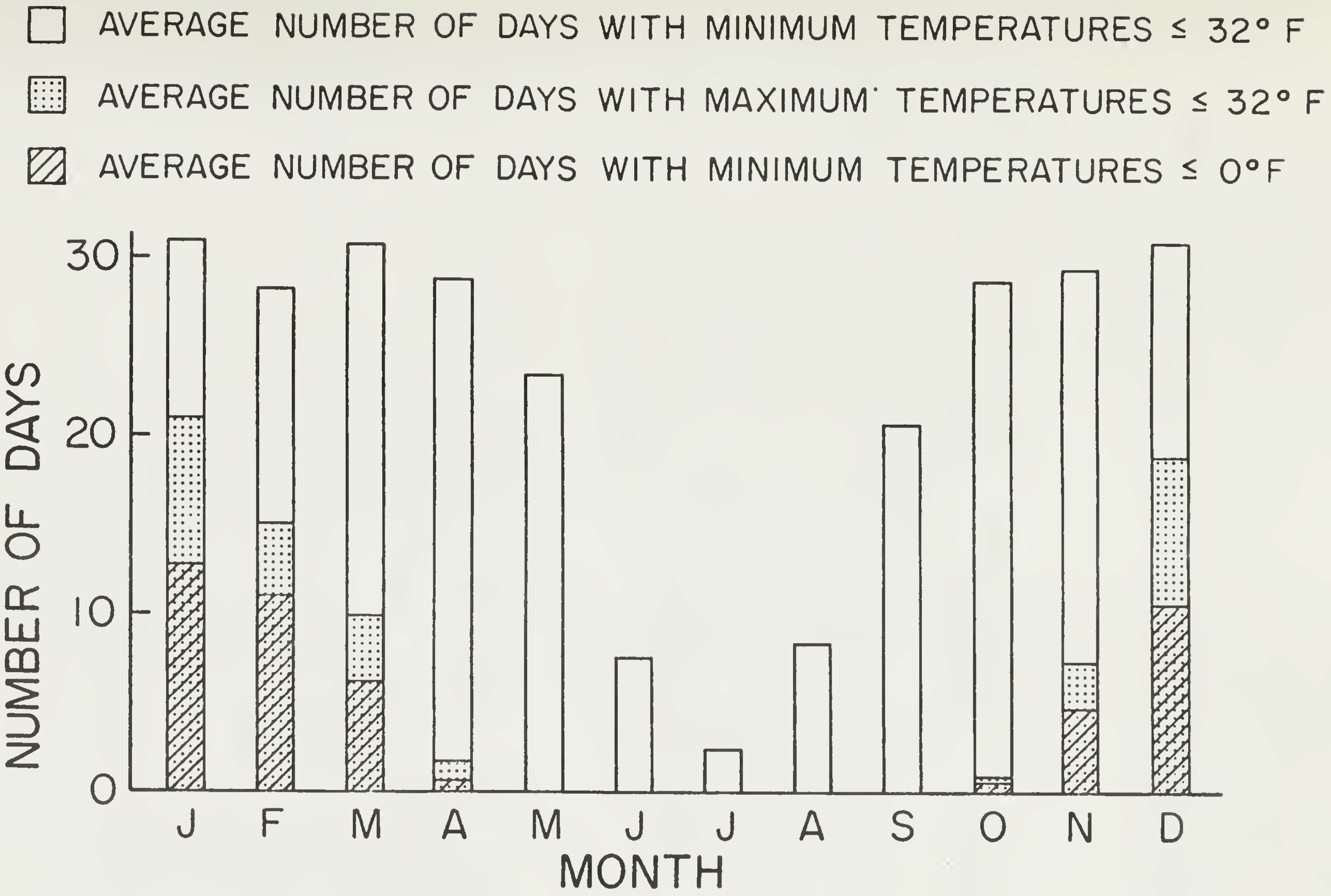


Figure 2. Average number of days with temperatures equal or below specified threshold values for Walden, Colorado, 1948-1975.

Table 1. Spring and fall freeze statistics and freeze-free periods for Walden, Colorado. (From Benci and McKee.)

		SPRING FREEZE			FALL FREEZE			FREEZE-FREE PERIOD (DAYS)			
Station	T°F	Mean Date	SD*	Last Date	Mean Date	SD*	First Date	Mean	SD*	Max.	Min.
Walden	32	7-05	12.1	7-20	8-07	11.9	7-21	33.	18.7	58.	1.
	28	6-16	14.7	7-09	8-22	13.1	7-28	67.	19.8	117.	40.
	24	5-29	12.8	7-01	9-06	9.2	8-22	100.	15.3	122.	60.
	20	5-14	7.3	5-28	9-11	11.5	8-22	120.	11.5	147.	103.
	16	5-04	10.6	5-19	9-26	10.2	9-09	145.	9.7	161.	127.

SD* = Standard Deviation

		SPRING					FALL				
		Probability That Last Spring Freeze Will Occur On or After Date					Probability That First Fall Freeze Will Occur On or Before Date				
Station	T°F	90	80	50	20	10	90	80	50	20	10
Walden	32	6-20	6-25	7-05	7-16	7-21	8-23	8-18	8-08	7-29	7-24
	28	5-28	6-04	6-16	6-29	7-05	9-08	9-03	8-23	8-12	8-06
	24	5-13	5-19	5-30	6-10	6-15	9-19	9-15	9-07	8-30	8-26
	20	5-05	5-08	5-14	5-21	5-24	9-27	9-22	9-12	9-02	8-28
	16	4-21	4-26	5-05	5-13	5-18	10-10	10-05	9-27	9-18	9-14

temperature ever recorded was 91°F, and temperatures above 85°F are quite unusual.

Average maximum, minimum, and mean temperatures for each day of the year at Walden are displayed in Figure 3. This figure gives a much more detailed accounting of the average march of daily temperatures through the year. Of particular interest is the smooth day to day variation noted in the summer months compared to the wildly fluctuating (even on a long-term average basis) daily temperature in winter.

Elevations within the interior of North Park generally only vary by a few hundred feet, but terrain features do have a pronounced effect on temperature. Lower elevation valley bottom locations, such as Walden, experience colder winter temperatures, larger diurnal temperature variations, higher daytime temperatures in the summer, and a shorter growing season than the higher lands between rivers. For example, the Spicer weather station southwest of Walden is 265 feet higher than the Walden station. The growing season is a few days longer at Spicer. Nighttime temperatures at Walden are cooler throughout the year and average 3 degrees F less than Spicer during midwinter. Extremely cold temperatures occur much more frequently at Walden. But high temperatures at Walden average about 2 degrees F warmer than Spicer during the summer. This same type of temperature variation can be expected to occur even in very local areas over a distance of only a few hundred feet. Therefore, temperature variations are likely to be encountered from one area to another on the McCallum site.

C. Precipitation

North Park is a semiarid area. The entire interior of North Park averages less than 16 inches of precipitation annually as shown in

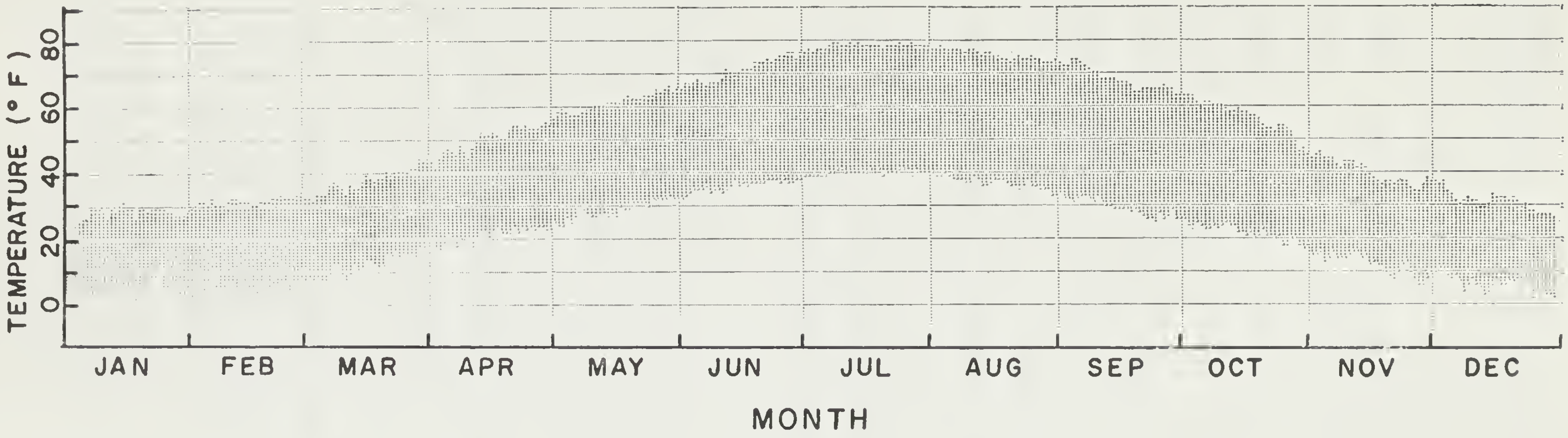


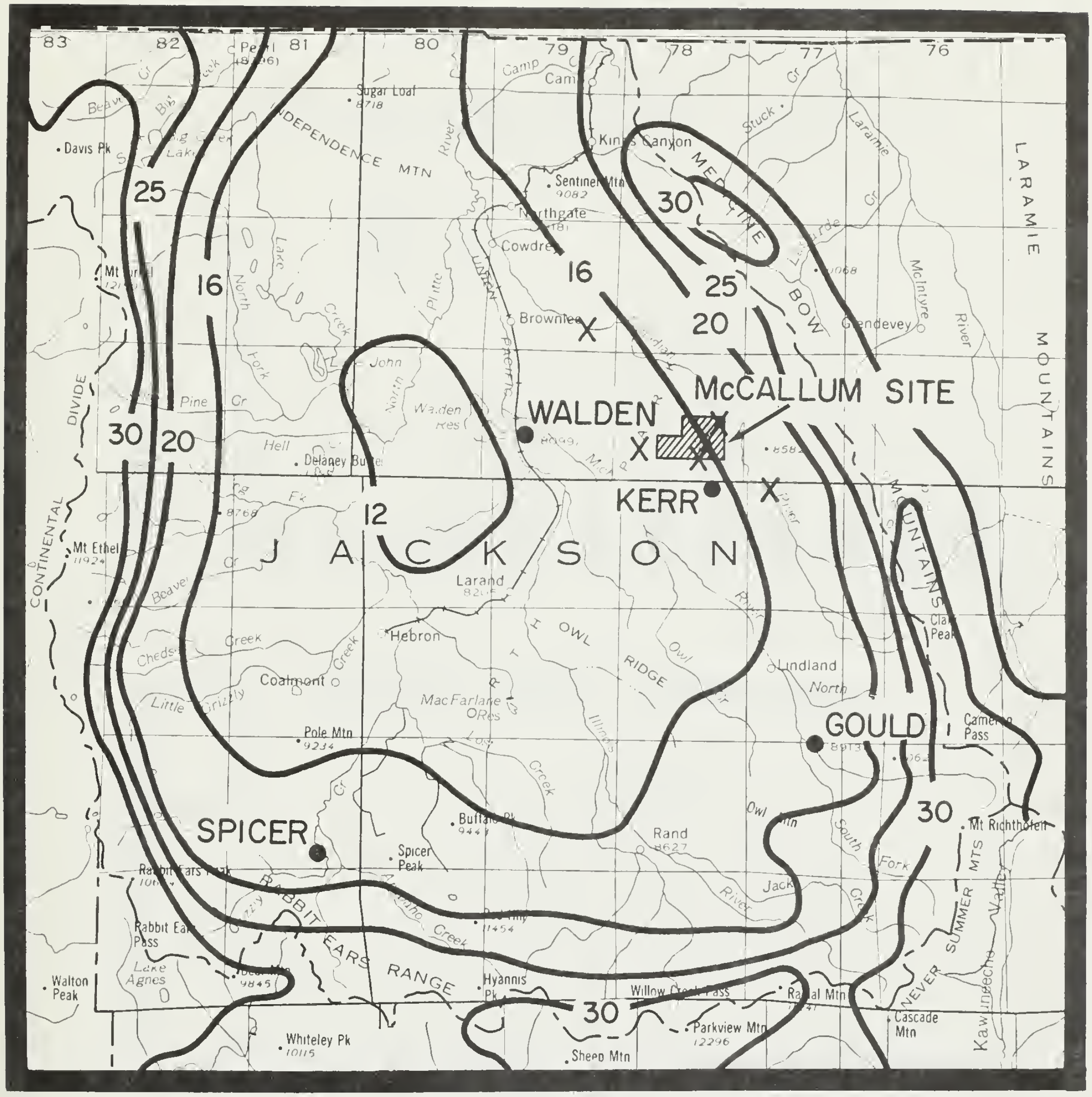
Figure 3. Average daily maximum, minimum, and mean temperatures in degrees Fahrenheit for Walden, Colorado, 1938-1979.

Figure 4. Measurements at Walden indicate that the annual average precipitation (1938-1979), including the water equivalent of winter snowfall, is only 9.67 inches which is less than the map analysis indicates. Since 1937, annual precipitation totals at Walden have ranged from a low of 5.92 inches in 1964 to a high of 13.56 inches in 1951.

Precipitation in the area is produced by three basic mechanisms: 1) large-scale organized storm systems, 2) orographic lifting caused by moist air rising over mountain ranges, and 3) convective thundershower activity. Strong large-scale storm systems generally occur only during the winter and spring seasons. Orographic lifting is a dominant factor during that same period when the westerly flow aloft over the mid-latitudes is strongest. Convective activity becomes the dominant precipitation mechanism during midsummer when the large-scale atmospheric circulation is weak but solar insolation and heating are strong.

1) Winter Precipitation

Winter (usually defined as October through April) is the driest time of the year in the center of North Park, even though the same period is the wettest season in many of the surrounding mountains. Winter water-equivalent precipitation in excess of 40 inches is common in parts of the Park Range west of Walden. However, as the westerly flow crosses the mountain barrier, the air descends over the park causing the air to warm and causing the clouds and precipitation to decrease before ascending the next mountain range. Thus, precipitation is minimized over the center of North Park. Monthly precipitation information for Walden is shown in Figure 5. Walden averages only about 4 inches of precipitation for the October through April period.



X = U.S. GEOLOGICAL SURVEY STATIONS

Figure 4. Estimated regional distribution of annual precipitation (in inches) for north central Colorado (from U.S. Weather Bureau for period 1931-1960). Note: Data for Walden for period 1938-1980 do not agree with this map.

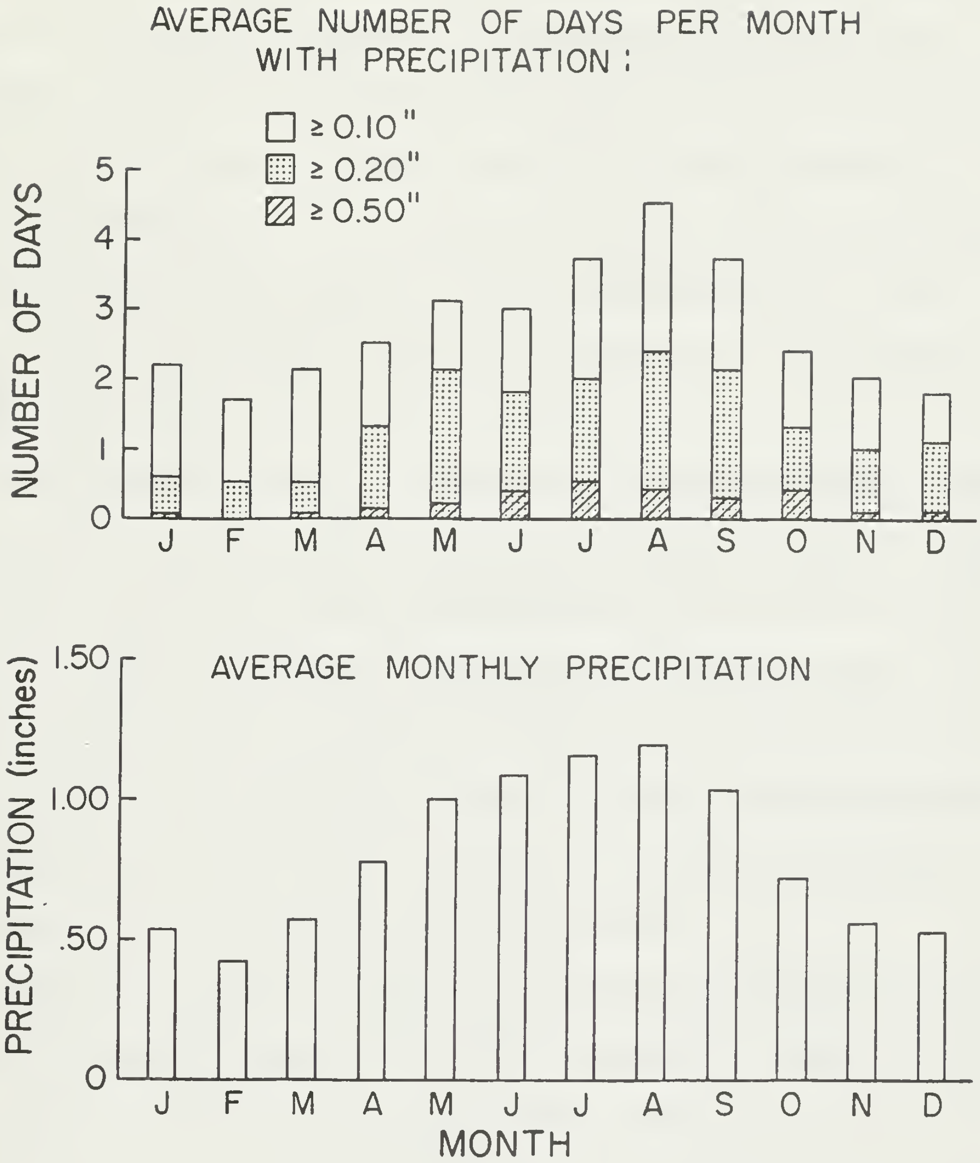


Figure 5. Monthly precipitation climatologies for Walden, Colorado, 1938-1975.

Practically all winter precipitation in the North Park region falls as snow. Most winter precipitation is associated with large scale storm systems which generate widespread upward motion and precipitation. The topography again plays an important role. Even in major storm situations, heavy precipitation is not likely in the interior portions of North Park because the low-level moisture sources necessary to produce heavy precipitation are blocked by the surrounding mountains. As a result, occurrences of daily precipitation amounts of 0.50 inches or greater are extremely rare during the winter.

Monthly average snowfall for Walden and the average number of days with an inch or more of snow on the ground is shown in Figure 6. Snowfall is not particularly heavy, averaging only 51 inches per year, but snow usually stays on the ground throughout the midwinter months. The snowmelt is almost always complete by early April, and the snow that falls in April, May and June usually melts quickly. Typical midwinter snowdepths at Walden are usually one foot or less although maximum depths up to nearly three feet have been recorded.

Snowfall and snowdepth increases are usually noted approaching the mountains surrounding Walden. The Spicer station, for example, averages 125 inches of snowfall annually, experiences snowdepths as great as 4 feet, and averages 151 days per year with an inch or more of snow on the ground, 41 days more than Walden. Eyewitness reports indicate that the McCallum site also receives more winter snowfall than Walden. However, these increases are not excessive. Generally, snowfall seems to change little from Walden eastward to the McCallum Study Area but then increases rapidly from there eastward across the Canadian River to the Medicine Bow Mountains.

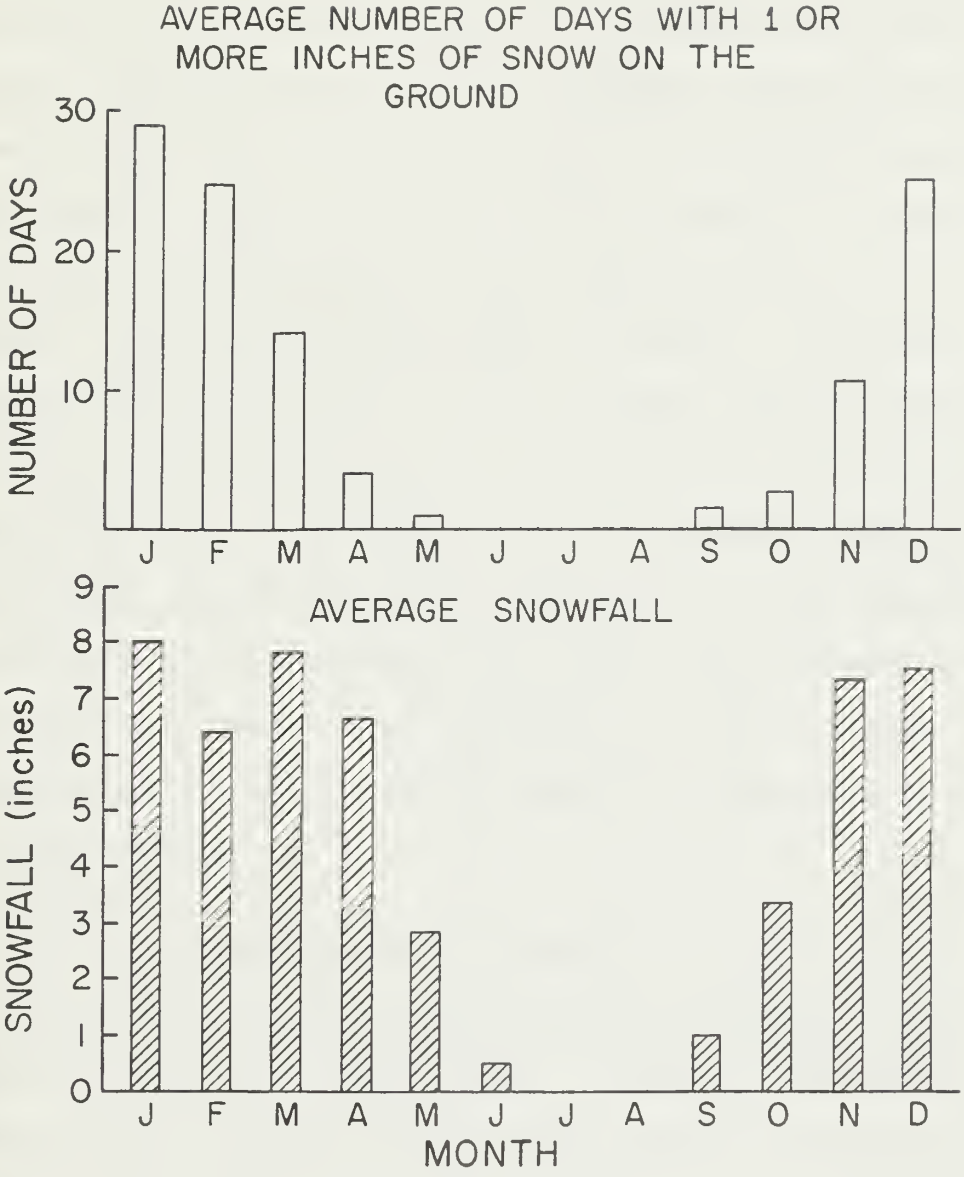


Figure 6. Average monthly snowfall (inches) and average number of days with snow on the ground for Walden, Colorado, 1938-1975.

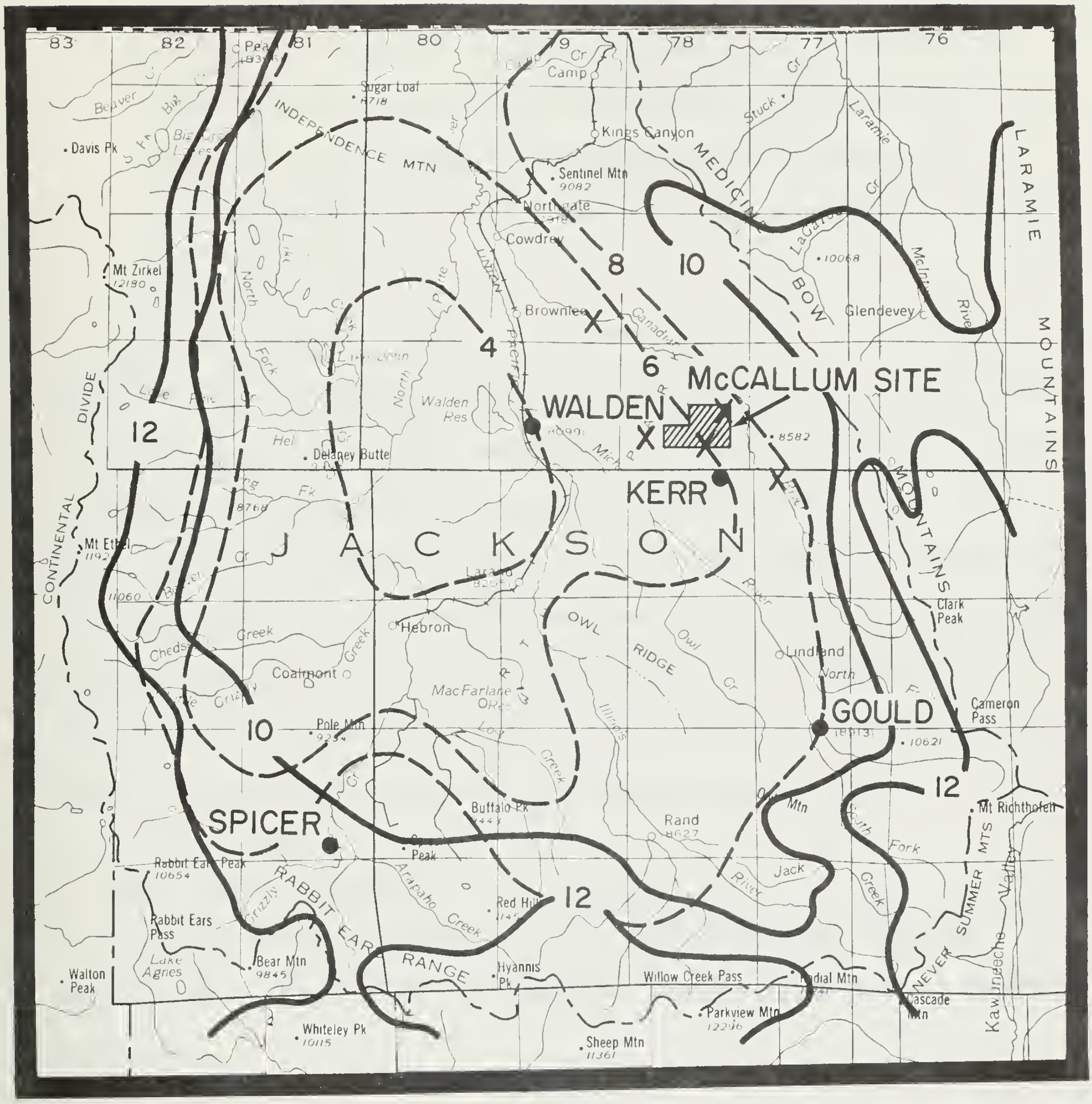
2) Summer Precipitation

The five summer months, May through September, account for about 60 percent of the annual percipitation in the Walden area (about 6 inches). From late June through early September, afternoon thundershower activity occurs frequently both over the surrounding mountains and across the center of North Park. Rainfall amounts are usually very light, however, because the storms have very limited moisture sources. The abundant low-level moisture necessary to generate severe thunderstorms and occasional heavy precipitation (characteristics of eastern Colorado and other Great Plains locations) is unable to cross the mountain barrier east of North Park. The greatest one-day precipitation total recorded at Walden was 2.19 inches, but daily amounts in excess of one inch are extremely rare. Daily rainfall amounts of 0.50 inches or greater only occur an average of two times each summer. Rainfall amounts of 0.10 inches or greater on the average occur only 18 days each summer.

3) Areal Distribution of Precipitation

An estimate of the quantity and distribution of annual precipitation for the North Park area was given in Figure 4. The companion map showing seasonal averages for May through September and October through April is shown in Figure 7. The basic characteristics of the distribution of precipitation in the park are as follows:

1) Summer precipitation, on the average, is quite uniform across the entire North Park area. Significant increases occur only as you rise into the higher mountains surrounding the park.



X = U.S. GEOLOGICAL SURVEY STATIONS

— — OCT-APR AVERAGE PRECIPITATION

—— MAY-SEP AVERAGE PRECIPITATION

Figure 7. Estimated regional distribution of seasonal precipitation (in inches) for north central Colorado (from U.S. Weather Bureau for period 1931-1960). Note: Data for Walden for period 1938-1980 do not agree with this map.

2) Winter precipitation is lowest in the center of North Park but increases with elevation and increases rapidly as you get closer to the surrounding mountain barriers, particularly the Park Range to the west and the Medicine Bow Mountains to the east.

The maps shown in Figures 4 and 7 were a result of analyses completed by the U.S. Weather Bureau in the 1960's based on 1931-1960 data. These maps have traditionally been used as the best reference for areal distribution of Colorado precipitation. Unfortunately, very little actual data were available in North Park for that period so the analysis has always been in doubt. Because reclamation activities are very sensitive to precipitation, accurate information is very important. A special analysis appears in Section V which attempts to assess precipitation characteristics specific to the McCallum Study Area.

D. Other Climatic Elements

Data are presently lacking in North Park to support detailed descriptions of other climatic elements. However, some general comments can be made.

1) Wind

North Park and the immediate McCallum site are prone to frequent and strong winds during winter and spring. The prevailing wind direction is from the southwest,and wind gusts in excess of 40 mph are not uncommon during the winter months. The result is considerable blowing snow which frequently causes very low visibilities and ground blizzard conditions. The blowing snow tends to pile up in huge drifts in protected areas while exposed areas are sometimes blown completely clear.

During the summer and early fall winds are more gentle and wind directions are dominated by local topography.

2) Solar Radiation

Little is known about the winter solar radiation averages and variations in North Park. However, during the summer months cloudiness and, hence, solar radiation is very similar across all of Colorado (Doesken et al., 1979). During the midsummer period a typical daily solar radiation total should equal about 60 percent of the extraterrestrial radiation (the amount of energy that would be received at the surface if there was no atmosphere to reflect, scatter, and absorb the sun's energy). For June 21 this would equal about 2300 BTU per square foot per day of solar energy reaching a horizontal surface in North Park.

3) Evaporation

Maximum evaporation rates occur in midsummer when temperatures are highest. Estimates suggest that the May through September Class A pan evaporation total should average about 35 inches in the Walden and central North Park area. This is consistent with actual pan evaporation measurements taken near Grand Lake and at Green Mountain Dam, which are weather stations south of Walden and North Park but at similar elevations.

IV. LOCAL CLIMATE DATA AND APPLICABILITY

A) Data Sources

Data used in this report have come from four locations in the North Park area.

1) Walden - National Weather Service, cooperative substation
2) Spicer - National Weather Service, cooperative substation
3) Gould - U.S. Forest Service Fire Weather Station
4) Kerr Coal Mine - private
5) Canadian River Precipitation Gages - U.S. Geological Survey

The location of these weather stations in relation to the McCallum Mining Site are shown in Figure 4. The types of available data from these stations and the years when data have been collected are shown in Table 2.

Basically, only daily temperature and precipitation data are readily available. Wind and humidity data are very sparse, and at this time no solar radiation or evaporation measurements in the immediate area have been taken.

B) Data Quality

Both the types of data being collected from these sites and the data quality are not uniform. The two National Weather Service substations are perhaps the most consistent. Both Walden and Spicer record daily temperatures and precipitation, have always employed the same instrumentation, and have always used the same observational procedure. However, each station has been moved several times during its long history. Although each station move was minor, the changes in instrument exposure and elevation changes relative to the rolling

Table 2. Weather data used in this report in the vicinity of the McCallum Mining Site.

LOCATION	TEMPERATURE	PRECIPITATION	WIND SPEED	WIND DIRECTION	HUMIDITY	OTHER
Walden lat. 40° 44' long. 106° 17' elev. 8115 ft.	Daily readings of 24-hour max and min 1897-1905 1938-present	Daily readings of 24-hour total precipitation, snowfall, and snowdepth 1887-1905 1938-present				
Spicer lat. 40° 27' long. 106° 28' elev. 8380 ft.	Daily readings of 24-hour max and min 1912-present	Daily readings of 24-hour total precipitation, snowfall, and snowdepth 1909-present				
Gould lat. 40° 32' long. 106° 2' elev. 8975 ft.	1:00 PM observation and daily readings of 24-hour max and min (for summer only) 1964-present	Daily readings of 24-hour total precip., precip. kind and duration, time precip. began and ended. (for summer only) 1964-present	1 obs. per day. 10 min. average in mph. (for summer only) 1964-present	1 obs. per day to nearest 45° (for summer only) 1964-present	Dry bulb and wet bulb temp. reading daily at 1:00 PM. (for summer only) 1964-present	State of weather; lightning activity (for summer only) 1964-present
Kerr Mine lat. 40° 42' long. 106° 7' elev. 8250 ft.	Daily readings of 24-hour max and min (reduced from continuous recording charts) 1978-present	Daily readings of 24-hour total precipitation. (Very poor quality) 1978-present	2 obs. per day. Noon and Midnight. 1978-present	Eyeball estimate from continuous charts of 12-hr prev. dir. 0600-1800, 1800-0600. 1978-present	2 obs. per day. Noon and Midnight. 1978-present	
Canadian River (5 stations) lat. 40° 42-49' lont. 106° 4-14' elev. 7990-8320 ft.		Daily readings of 24-hour total precipitation reduced from recording gage charts 1978-present				

terrain of North Park could have significantly affected the observations, especially of minimum temperatures. Despite these potential problems, the quality of data from both stations is very good.

The weather station at Gould has been in operation since 1964 on a summer-only (approximately late May through October) basis for the U.S. Forest Service in support of the fire weather monitoring program. Instruments are compatible with National Weather Service equipment, and data quality is satisfactory. One observation of wind and humidity each day is a helpful addition to the temperature and precipitation data at Walden and Spicer.

Data have been collected at the Kerr Coal Mine adjacent to the McCallum Study Area since January 1978. This is a detailed data set containing both wind and humidity observations as well as temperature and precipitation. Unfortunately, however, it has many problems. The instruments used, mostly electronic sensors, are not identical to the equipment at Walden, Spicer, and Gould. It is not known how well they should compare. Also, there is a large percentage of missing and/or suspicious data. Since the station automatically records and stores information, and because the organization collecting the data has no need to monitor the data regularly, problems developed which were not promptly discovered and corrected. Thus, while the data could be of great value, the missing data and uncertainties in the existing data degrade it considerably.

The U.S. Geological Survey has been measuring precipitation at several sites in the Canadian River drainage north and east of Walden beginning in 1978. Two different types of gages have been employed and some but not all of the gages are shielded to minimize wind effects.

Problems with winter snow catch have been noted and missing data have occasionally been a problem. The data may not be complete or exactly compatible with the other weather stations in North Park, and data sets are of short duration. However, the data quality appears to be good, and those stations should be a useful supplement to existing longer-term stations.

C) Data Applicability

Climatic conditions can vary greatly over surprisingly short distances, particularly in mountainous terrain. Ideally, many years of measurements of all pertinent climatic parameters should be taken on the site of future mining and reclamation activities to assure an accurate climatic description. Since this was not the case at the McCallum site, the representativeness and applicability of existing data must be assessed.

The weather station at the Kerr Coal Mine is very close to the McCallum site (see Figure 4). All aspects of the local climate should be very similar since their elevations and locations relative to the surrounding mountains are practically identical.

The climate of Walden should also be very similar to that of the McCallum site. Although the McCallum site is closer than Walden to the mountains on the east side of North Park, elevations are similar at both locations and temperatures at Walden should be representative. Some precipitation differences may be noted during the winter season as snowfall begins to increase eastward from Walden toward the Medicine Bow Mountains. This will be discussed thoroughly in Section V.

Spicer is a considerable distance from the McCallum site and is located on the opposite side of North Park. Winter precipitation is considerably greater there, and temperatures differ significantly from the eastern portion of North Park. While not being totally representative of the McCallum site, this station does offer a good comparison to show how climatic conditions vary within the park.

The Gould site is also a considerable distance away. It is several hundred feet higher and is located within the forested area near the base of the Medicine Bow Mountains. Measurements are taken there only during the summer when conditions are more nearly uniform across the area. However, significant differences especially in temperature would still be expected between Gould and the McCallum site.

The Canadian River precipitation gages operated by the U.S. Geological Survey are located in the immediate vicinity of the McCallum Study Area. They should yield representative data for the areas and should help greatly in determining the magnitude and distribution of precipitation on the east side of North Park.

Due to the quantity, quality and locations of existing data, the Walden daily temperature and precipitation records offer the greatest potential for climatic analyses and will be used extensively throughout this study. Limited summer data from the Gould station will also be included. Due to its short duration and questionable quality, Kerr Mine site data will be used only as background reference to the authors. U.S. Geological Survey data, although short in duration, will be used to help assess the distribution of precipitation near the McCallum site. Data from Spicer will only be used to indicate the type of variations which can be expected from one location to another in North Park.

V. CLIMATE PROFILES FOR RECLAMATION

The real objective of the climate profile is to provide climatic information which is useful in decision making in the various reclamation activities. The approach used here is to identify the reclamation activities, determine the activities which are sensitive to climate, and develop climatic analyses pertinent to each activity. Each of these aspects will be addressed in this section.

A. Reclamation Activities

Reclamation activities are identified in the first column in Table 3. The sequence of activities includes: vegetation selection, spoil placement and grading, topsoil placement, surface treatment, soil preparation, and planting. Vegetation selection is the first step. It is in the vegetation selection step where the restrictions emerge which climate places upon vegetation. If the climate applies severe limitations on the germination and survival of new vegetation, then the remaining reclamation activities can be adjusted to best suit the particular vegetation which has been selected. Climatic analyses will be presented in a later section in response to the problems and opportunities arising in each activity.

B. Vegetation Selection

Plant selection for successful revegetation of over-burden or mine spoils is not an exact science. Subjective procedures have typically been used to select plants whose growth-cycle requirements (for germination, establishment, growth, flowering and fruiting, and reproduction) are satisfied by the local environment. Climate is not the only environmental factor to contend with. Soil type and available nutrients

TABLE 3. CLIMATE ANALYSES FOR RECLAMATION

Reclamation Activity	Problems/Opportunities	Climate Analyses
I. Vegetation Selection	1. Establishment and survival of plants	1, 2, 5, 6, 7, 8, 10, 12, 13
II. Spoil Placement and Grading	Problems: 1. Transport by wind and runoff --shape, orientation, height --surface roughness --particle size 2. Road location and construction --snow accumulation --drainage --slope Opportunities: 1. Create microclimate favorable to vegetation --control wind --enhance snow accumulation --reduce evapotranspiration	4, 7, 8, 9, 10, 11, 13, 14, 15
III. Top Soil Placement	Problems: 1. Transport by wind and runoff	4, 8, 10, 11, 14, 15
IV. Surface Treatment (pitting, imprinting, contouring, disking, and raking)	Problems: 1. Control surface runoff and erosion 2. Trafficability Opportunities: 1. Provide favorable germination sites 2. Increase soil water	4, 8, 9, 10, 11, 13, 14, 15
V. Soil Preparation	Problems: 1. Trafficability Decisions: 1. Mulching --soil depth, water capacity 2. Supplemental water 3. Fertilizer --soil character	4, 6, 7, 8, 10, 13
VI. Planting	Problems: 1. Trafficability 2. Timing for seeding or transplanting --germination --growth and establishment 3. Seeding rate	1, 2, 3, 6, 7, 8, 10, 12

CLIMATE ANALYSES

1. Freeze-Free Period.
2. Growing Season.
3. Late Warm Periods.
4. Freezing Temperature Threshold.
5. Extreme Temperatures.
6. McCallum Site Precipitation.
7. Annual and Seasonal Variability.
8. Precipitation Frequency and Intensity.
9. Snowfall Frequency and Intensity.
10. Snow Accumulation and Snowmelt.
11. Large Rain Events - Return Periods.
12. Growing Season - Joint Probability.
13. Growing Season Potential Evapotranspiration Minus Total Precipitation.

*14. Frequency Distribution of Wind Speed and Direction.

*15. Probability of High Winds.

* Not available due to lack of data.

are limiting factors in any revegetation activity. However, climatic conditions are of primary importance and must be taken into consideration.

Growth-cycle requirements for plants are closely coupled to the climate through temperature (air and soil), precipitation, atmospheric water content (vapor pressure or relative humidity), and solar radiation (heat and light). Seldom are plants and climate coupled through a single climatic characteristic, independent of the others. As a rule, it is the interrelation of the climatic characteristics that couples the plant to the climate. For example, the interrelation of temperature, relative humidity, wind, and the energy balance determine the evaporative demand, which is the coupling between the climate and plant functions.

Plant-climate couplings are very complex, and the basic data needed to completely define the interrelations are generally lacking. However, simple temperature and precipitation indexes and threshold values can provide very useful information.

Precipitation, or more precisely the amount of moisture present in the topsoil (which is generally controlled by precipitation), is critical for determining what plants have a chance for survival. Regardless of other climatic characteristics of an area, precipitation must be adequate or supplemental water must be available to support vegetation.

For vegetation selection the most important precipitation characteristics are summer season or growing season amounts, off season or winter season amounts (which contribute to soil moisture), and reliability. It is generally the amount of precipitation which falls in the driest years (or seasons), rather than the average amount of precipitation, which determines what plants will eventually survive.

Assuming that a plant's moisture requirements can be met, then temperature characteristics play a dominant role in the germination, establishment, and growth of plants. Elevation ranges and temperature extremes limit the types of vegetation which can grow in a given area. Many cool-season grass seeds require stratification during the preceding winter to later produce flowers and seeds. Temperature requirements must also be met for high rates of germination. Temperature continues to play an important role in the establishment of new plants as they develop the root and shoot systems to support themselves independently of the food stored in the seed. Once a plant is established, and water is not limiting, completion of the growth cycle has been sucessfully described as a function of temperature-based indexes, such as heat units or degree days. Temperature-based indexes for many agricultural crops have been established with enough reliability so that they can be used to predict the date of flowering and crop maturation. Unfortunately, such temperature-based indexes are known for only a small number of species commonly used for revegetation.

There are useful climatic characteristics that can be used as guides for judging the ease or difficulty of revegetation. These characteristics include: temperatures during the beginning or end of the growing season which may preclude germination or terminate active growth, various definitions of the length of the growing season, and the probability of periods within the growing season that are more favorable for plant growth.

Critical climatic elements related to vegetation selection are shown in Table 4. Where analyses have been completed, values of these critical climatic parameters have been filled in for the McCallum site. More detailed information concerning some of these analyses is given

Table 4. Plant Requirements for Vegetation Selection

	CLIMATE ELEMENT															
	Elevation Above Sea Level	Long Term Mean Annual Air Temperature	High Temperature Extreme	Hottest Temperature Experienced Every Year	Low Temperature Extreme	Coldest Temperature Experienced Every Year	Freeze-Free Period	Potential Thermal Growing Season (Probability = .5)	Growing Degree 40° F Base	Annual Precipitation	Driest Years (Probability = .10)	May-September Total Precipitation	Driest Summer (Probability = .10)	October-April Total Precipitation	Driest Winter (Probability = .10)	May-September Potential Evapotranspiration
P L A N T	feet	°F	°F	°F	°F	°F	Days	Days	Degree Day	Inches	Inches	Inches	Inches	Inches	Inches	Inches
Climatic Profile McCallum Study Area*	8300	36	91	83	-49	-20	35	156	not yet computed	11	8.00	6	3.50	5	3.00	22
Plant 1																
Plant 2																
Plant 3																
. . . . .																

* Estimates made for the McCallum Study Area based on Walden and other North Park data.

in Section V D. Table 4 is not intended to be a complete listing of all elements and analyses pertinent to plant germination and growth. The major limitation of Table 4 is that the corresponding information for several plant candidates is conspicuously absent. If the actual specific requirements were available for all or many plant candidates, vegetation selection would be a straightforward task, and Table 4 could be used as an important guide. By comparing plant requirements to actual climatic conditions, plants most suited to the existing climate could be chosen. Inclusion of soil and nutrient information in the table would make it even more useful.

For future reclamation activities it will be very important to fill in these voids of missing information. Detailed climatic, soil, and nutrient information already can be obtained. When the related species sensitivity data become better known and more available, vegetation selection should become more objective and revegetation success should improve.

In the absence of detailed plant information and recognizing the goals of revegetation, there are various operational ways to go about plant selection using climate information in a much more general way. The first, and most obvious step is to consider the local native plant populations. Detailed quantitative scientific information may not be available for these plants, and conditions may not always be favorable for easy germination and establishment of these species. However, they clearly are adapted to the local climate and have proven their ability to survive.

Other methods can be employed. Local experience can be provided by seed suppliers, State Extension Agents, or others who have succeeded

in establishing vegetation on nearby sites. Where no experience is available locally, general guides are available (Cook, Hyde, and Sims, 1974; Hafenricher, Schwendiman, Harris, and MacLauchlan, 1968; Vories and Sims, 1977). For a specific site, one can carry out experimental field studies. In the absence of appropriate information, one can forego field experiments and carry out the entire revegetation program using a rational trial-and-error approach.

C. Climate Problems/Opportunities in Reclamation

The sensitivity of reclamation activities to climate brings forth both problems and opportunities. Climate can influence when and where reclamation work can be done, it can limit the types of vegetation capable of survival, and it can dictate how successful a given reclamation strategy will be. But climate can also be viewed as an asset presenting special opportunities. For example, land can be shaped and contoured during reclamation to take full advantage of local climatic characteristics in order to increase the reclamation potential.

A list of particular problems and opportunities associated with each reclamation activity is presented in Table 3 (page 25). The first activity, vegetation selection, has been discussed thoroughly in the previous section. The primary problem, and also the final goal, is the establishment and survival of plants on the reclamation site. All aspects of climate are related to this crucial step.

For the reclamation activity of spoil placement and grading, the primary problems are material transport by wind and runoff and road location and construction. In each of these cases several different climate elements are involved.

For material transport by wind and runoff the primary sensitivity is to wind speed and precipitation. Material can become airborne by high winds, blasting, and surface traffic. Movement of the airborne material will then depend on wind speed and temperature stability. Material transport by water is due either to heavy precipitation or melting snow which leads to runoff and erosion. The spoil placement and grading activity can control these to a degree through the shape, orientation, height, surface roughness, particle size, and the density of material actually distributed. Thus, the climate information can be used to help design the correct characteristics of spoil placement and grading.

Climatically, road location and construction are primarily sensitive to precipitation and snowfall. Water erosion and drifting snow are the major problems encountered.

Opportunities as well as problems arise during the spoil placement and grading activity. Microclimates can be created which enhance the probabilities of revegetation success. Spoil placement, shaping and contouring can modify wind, incident sunlight, snow accumulation and runoff, all of which affect the local water balance and, hence, vegetation.

The reclamation activities related to topsoil, surface treatment, and soil preparation all face the same basic climate-related problems as does spoil placement and grading. Precipitation and wind, and their effects on transport of surface material, are again the major elements. The surface treatment aspect (including treatment types of pitting, imprinting, contouring, disking or raking) presents opportunities. For example, favorable seed germination sites can be provided.

Also, the soil's capacity to hold water could be increased in specific locations.

The task of soil preparation has a separate set of decisions that appear that include mulching, whether or not to use supplemental water, and whether or not to fertilize. Each should be considered in context with the moisture that is available or the precipitation that is likely to occur during the time of soil preparation.

Finally, the planting activity has several associated problems and decisions caused or affected by climate. The best method of planting (drilling, broadcasting, hydroseeding, or transplanting) must be determined, and the selection of optimal planting dates is crucial. Basic seed and plant responses to the climate are, of course, the deciding factors here. But other elements such as surface trafficability and human comfort should not be overlooked.

D. Climate Analyses for Reclamation

A variety of climate analyses have been performed. These analyses are intended to assist and support the planning and decision making processes leading to a comprehensive reclamation strategy. However, these analyses cannot necessarily stand alone. They must be viewed and interpreted in context with available biologic, hydrologic, geologic, and edaphic information.

Many of the climate analyses are presented in terms of probability. This is by far the most realistic way to view climate since climate is not a static element of the environment. Natural climate variations are sufficiently great that it is not possible to precisely anticipate climatic conditions for a given time and place (as suggested by climatic averages or normals). However, from the historical record

it is possible to accurately estimate the most likely range and distribution of these climatic conditions, and to determine the frequency of occurrence of adverse conditions which could be detrimental to reclamation success.

1) Temperature analyses

Several specific climate analyses of temperature are presented here. Results of these analyses are described along with comments on how these results pertain to reclamation and revegetation problems and opportunities.

a) freeze-free period

A table of freeze-free periods for Walden was presented in Section II. This information is presented graphically in Figure 8 which shows average dates for the last spring occurrence and first fall occurrence of temperatures ≤ 32°, 28°, 24°, 20°, and 16°F. Also shown are the latest spring occurrence and earliest fall occurrence as well as standard deviations to indicate how these dates are climatically distributed.

The average number of days between last spring and first fall occurrence of ≤ 32°F is 33 days with an observed range from 1 to 58 days. If the threshold of 28°F is used, the average period between occurrences is 67 days with a range from 40 to 117 days. This type of information applies to the vegetation selection step of reclamation. Only those plants which can tolerate short growing seasons have a chance for survival and establishment at the McCallum site. Different temperature thresholds are used in addition to the 32°F value because the temperature of a "killing frost" varies a great deal from one plant species to another.

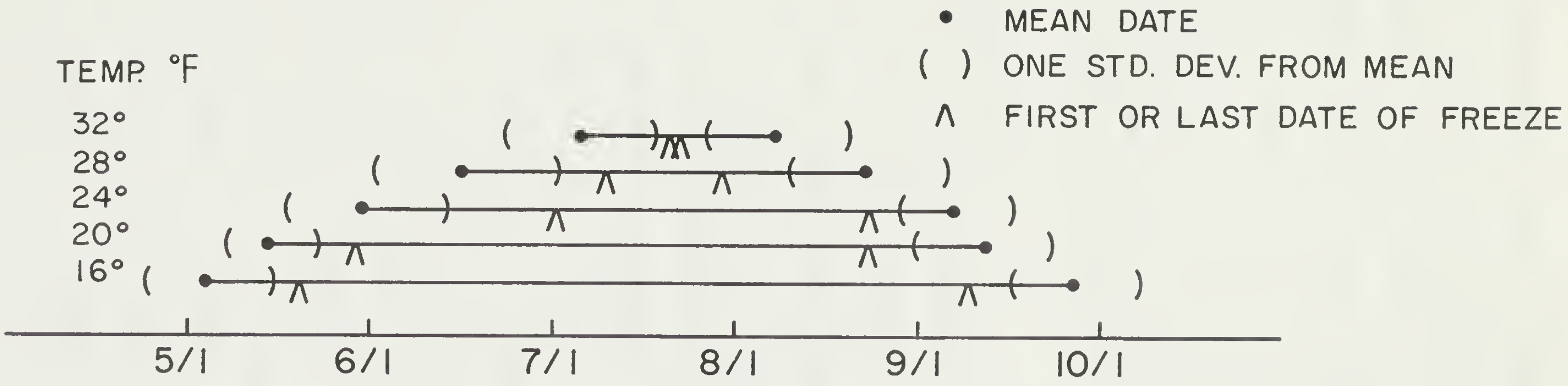


Figure 8. Freeze-free periods at Walden, Colorado, 1951-1970 (Benci and McKee, 1977).

This same information is shown in Figure 9 in terms of probabilities. The distributions of the last spring occurrence and first fall occurrence of minimum temperatures of $\leq$ 32°, 24°, and 16°F are plotted. The distance between related curves at a given probability is then the maximum freeze-free period for that probability. For example, there is a 90% likelihood (0.90) that the last spring occurrence of $\leq$ 32°F will occur on or after June 20, the first fall occurrence will occur on or before August 23, and the freeze-free period will be $\leq$ 62 days.

b) growing season

Freeze-free periods described above are often used to define growing season. However, the freeze-free period does not always correlate well with actual plant response because it is difficult to 1) establish the air temperature for defining the "killing frost" and 2) establish the duration of time during which the air temperature remains below the threshold air temperature. Also, frost can occur when measured air temperature is above 32°F.

Many plants (particularly cool-season grasses) can "green-up" and remain green when air temperatures are below freezing. Although the plants are green, they are not actively growing. The synthesis of many studies suggests that the potential period of active growth for many temperate plants occurs when the average air temperature remains above 40°F. Since the first warm spring day does not necessarily insure that the growing season has begun, an end-element running mean air temperature is used to establish the beginning (and ending) of what is called the potential thermal growing season. This information is of great importance in vegetation selection and also in estimating the success potential of revegetation activities.

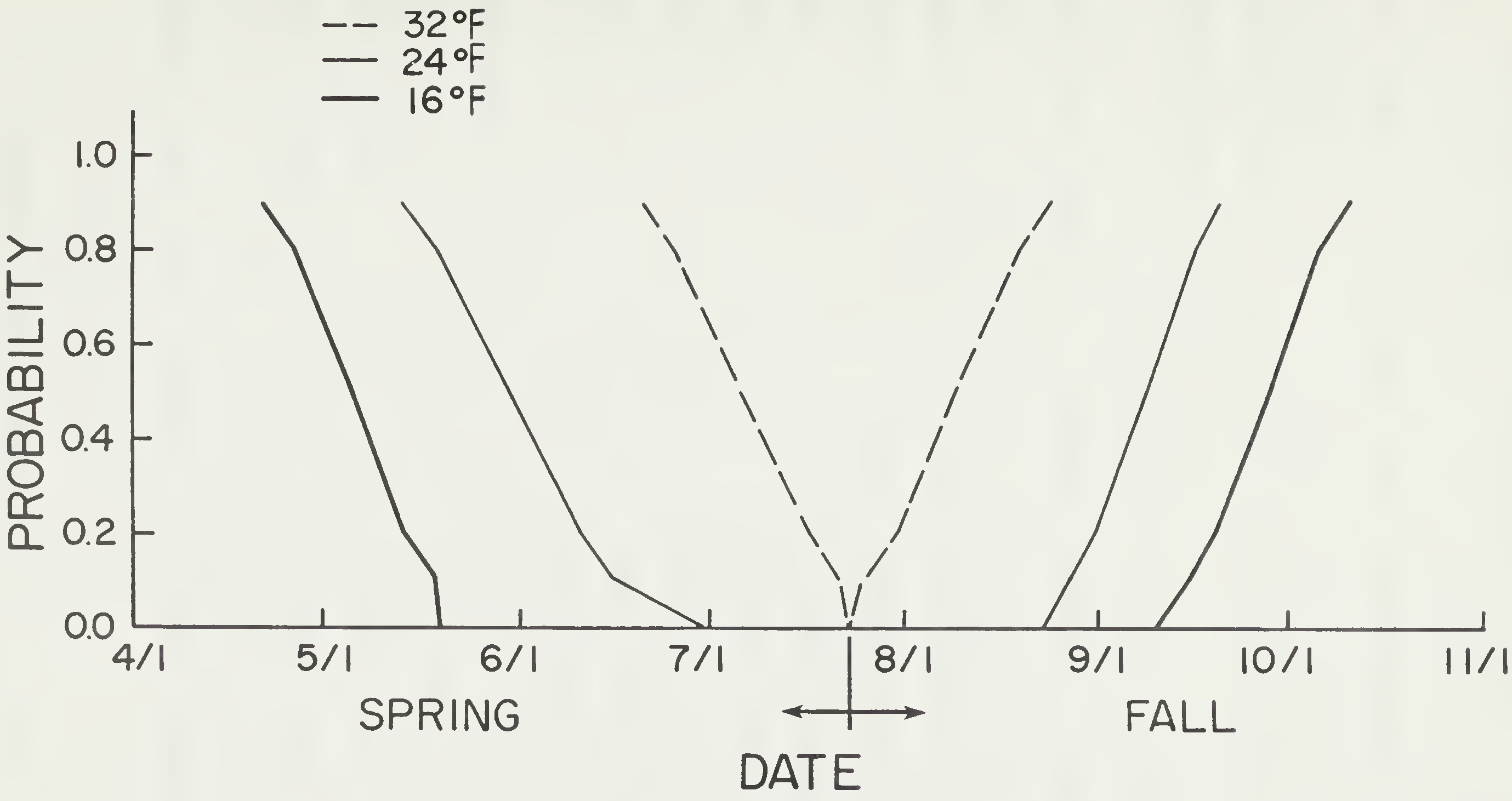


Figure 9. Probability that the freeze-free period at Walden, Colorado, is equal to or shorter than the corresponding intervals between the spring and fall curves for 32°F, 24°F, and 16°F. Spring curves show the probability distributions of the last occurrence each spring of temperatures ≤ each threshold. Fall curves show similar distributions of the first occurrence each fall of temperatures ≤ the same thresholds for the period 1951-1970.

In the usual calculation of a running mean, the average air temperature replaces the middle element in the run. For example, for a 7-day running mean, the average value replaces the 4th element in the run. If the running mean was used to define the growing season, it would imply that the plants know the temperatures for the next 3 days in advance. To solve this problem, the running mean average replaces the end-element in the run when it is used to define the potential thermal growing season.

Using the 1938-1979 weather record for Walden, the end-element 7-day running mean air temperature above 40°F was calculated for each year. The probability that the 7-day running mean air temperature was above 40°F was calculated. This curve is shown in Figure 10. From this graph one can see that a potential thermal growing season of about 100 days is virtually certain. The median growing season length is about 150 days (probability of 0.50). Longer and longer growing seasons become less and less frequent, with a 200-day growing season occurring with a probability less than 0.01. These growing seasons are much longer than what was indicated from the freeze-free analysis. Also the season is shifted more towards the fall. Part of this results from the fact that the final day of the 7-day running mean is used rather than the midpoint. It is also a result of the fact that later in the season daytime temperatures continue to stay rather warm while nighttime readings drop quickly. Thus, the 7-day running mean temperature stays above 40° long after subfreezing nighttime temperatures begin to occur.

c) late warm periods

Figure 11 shows the probability of having at least one occurrence of a 3, 5, or 7-day period having a mean temperature > 40°F at

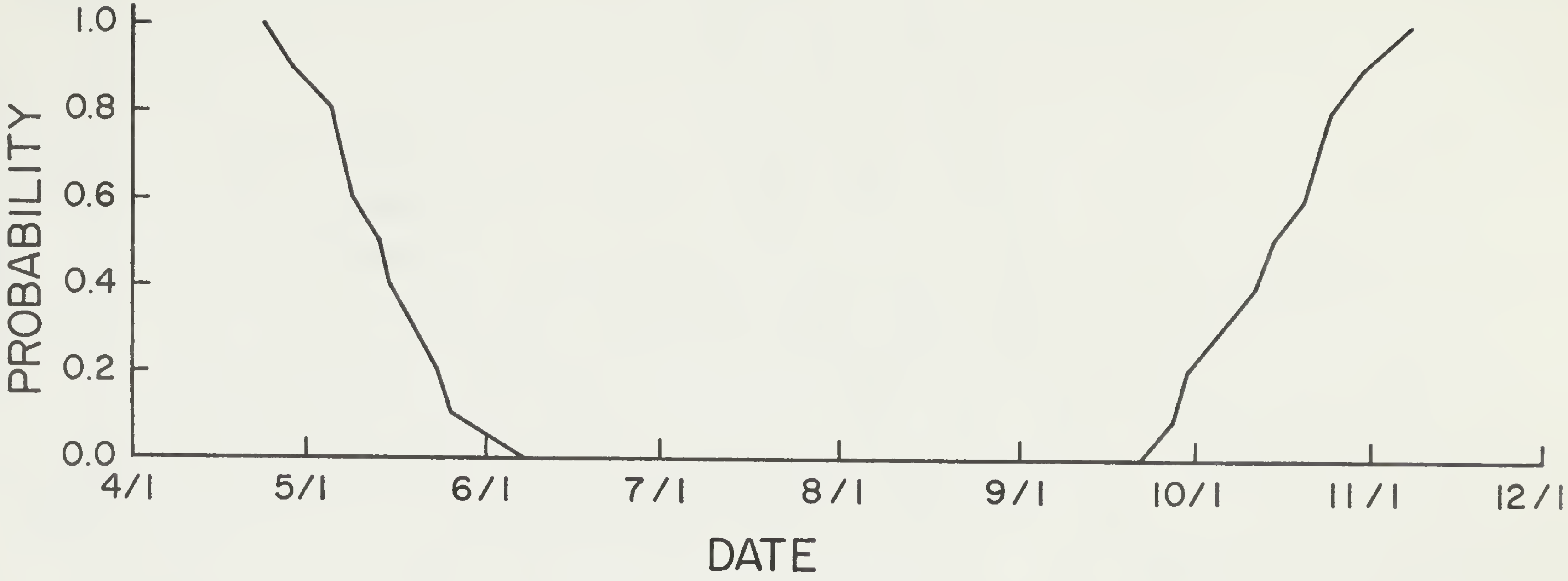


Figure 10. Probability that the potential thermal growing season (the period of time that the end-element 7-day running mean air temperature remains continuously above 40°F) is equal to or shorter than the corresponding interval between the spring and fall curves at Walden, Colorado. Spring and fall probability distributions are based on 1938-1979 data.

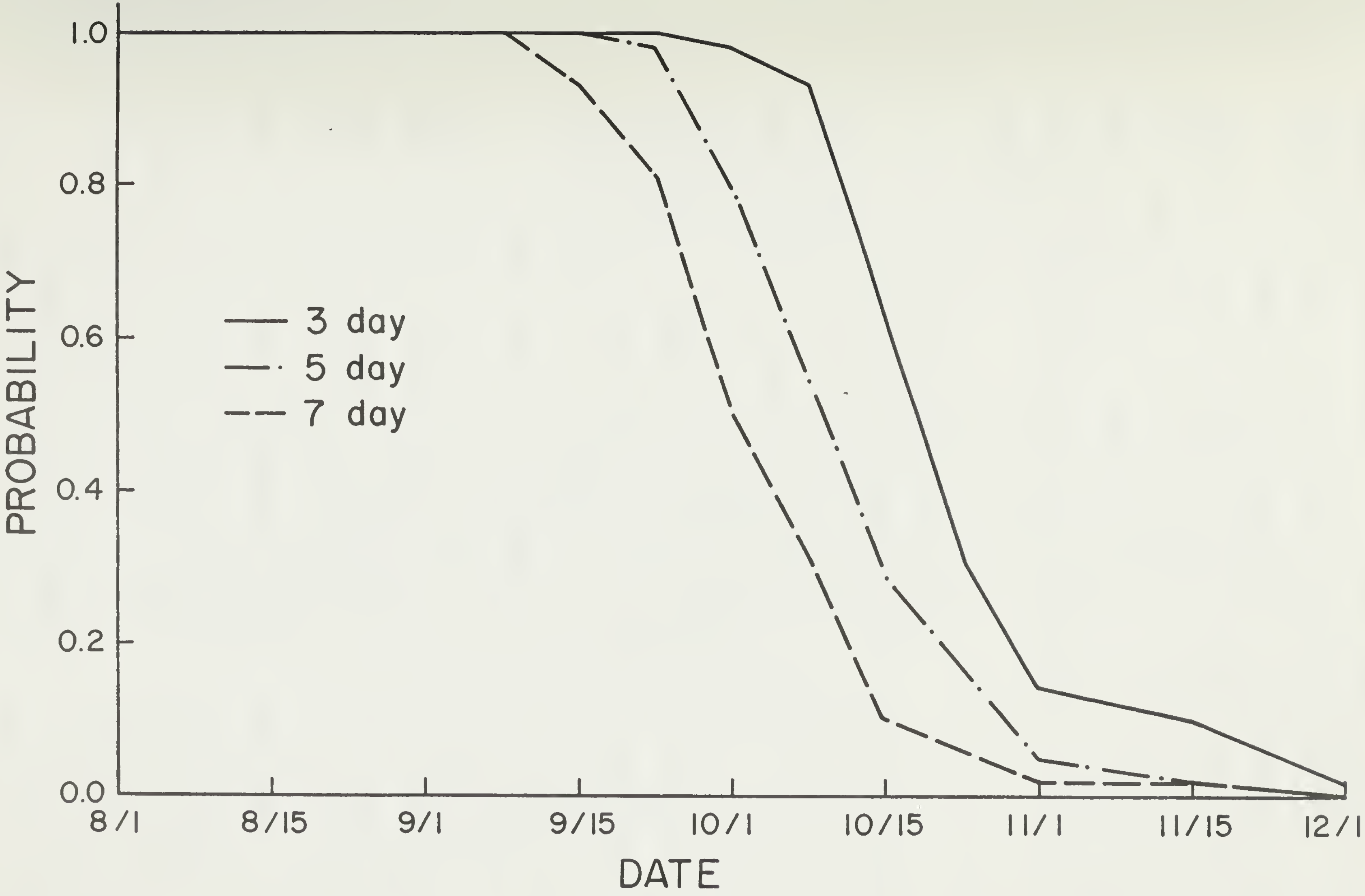


Figure 11. Probability of at least one occurrence of an n-day period with mean temperature > 40°F after given date. Walden, Colorado, 1938-1979.

Walden after specified dates. Such warm periods can lead to premature germination of fall-planted seed if moisture is available.

An example of the interpretation of this graph is: 50% of the time there is still at least one occurrence of a 7-day period with a mean temperature > 40°F after October 1. For a 3-day period, the equivalent 50% date is much later, October 18. There have been occurrences of 3-day periods with a mean temperature > 40°F as late as December 1.

d) freezing temperature threshold

The amount of time temperature stays above the freezing point, drops below the freezing point, or rises and falls above and below freezing all impact on reclamation activities. Figure 12 is a visual display of days each year with A) minimum temperatures above 32°F and B) maximum temperatures above 32°F. By observing the density and distribution of asterisks in the figure it is easy to quickly assess when these temperature thresholds are exceeded and for how many consecutive days.

Visual information on length and variability of freeze-free periods is one of the items which can be seen in Figure 12A. This relates not only to growing season but also to such things as periods of potential rapid snowmelt in late winter and spring (affecting trafficability and erosion potential) and periods of late season warmth which could initiate premature germination of fall planted seeds. It also shows, by considering all blank areas on the graph (days when minimum temperature falls to 32°F or below), days on which at least the surface layers of the ground may have been frozen for some period of time.

The occurrences of daytime temperatures above 32°F (blank areas are therefore days with maximum temperatures $\leq$ 32°F) are shown

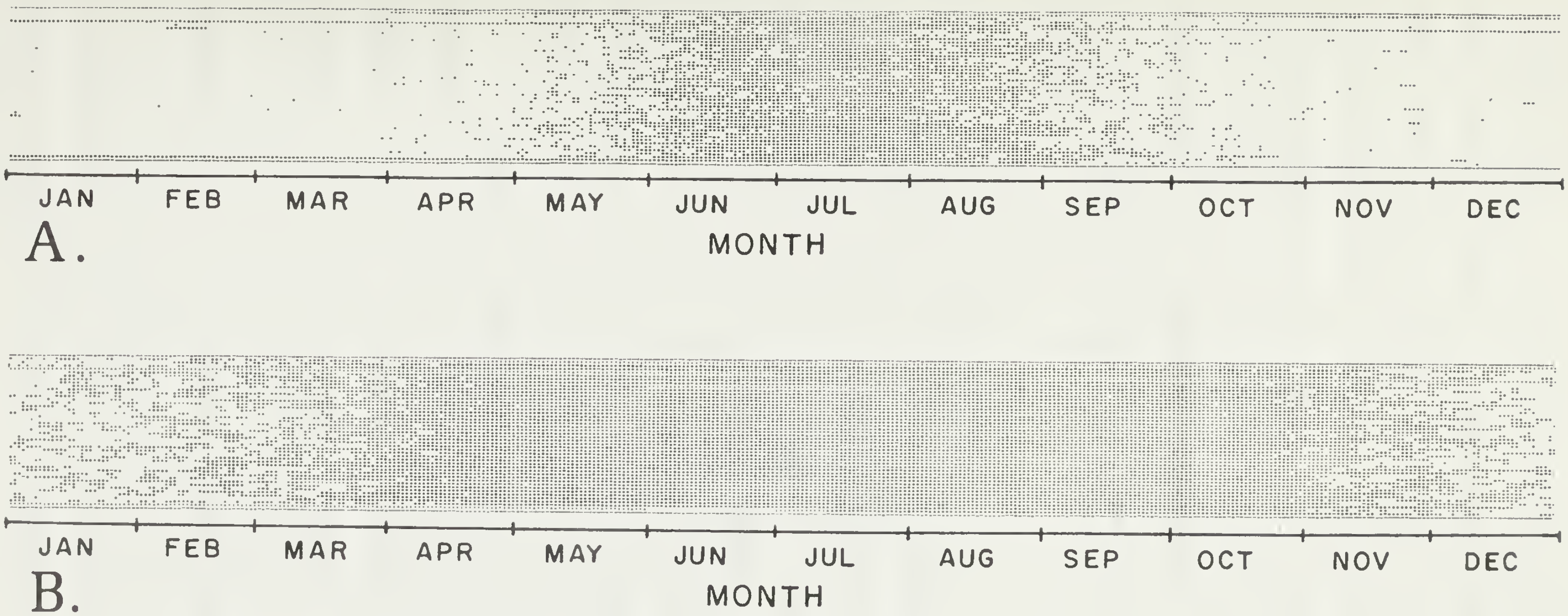


Figure 12. Density distribution of days with A) minimum temperatures above 32°F, and B) maximum temperatures above 32°F, at Walden, Colorado, 1938-1980.

in Figure 12B. This shows that even in midwinter, daytime temperatures often exceed 32°F which, in combination with Figure 12A, indicates frequent freeze-thaw cycles at the surface. This contributes to melting and structural change in existing snowcover and also tends to break up and loosen topsoil making exposed areas prone to wind erosion. The high frequency of above-freezing daytime temperatures in midwinter along with extremely cold nighttime temperatures cause special stress problems for poorly adapted plants. This should be considered during vegetation selection.

e) extreme temperatures

The probability that the daily minimum temperature will drop to various cold temperature thresholds on any day during the winter months at Walden is shown in Figure 13. Temperatures of 0°F or colder can occur at any time from October through April. From late November to early March there is at least a 1 in 4 chance on each day that the minimum temperature will fall to 0°F or below. The first 10 days of January is the period most likely to experience severe cold.

Temperatures below 0°F indicate a high probability of human discomfort. Of greater importance, in terms of reclamation, are the potential effects of extremely cold temperatures on vegetation. Temperatures $\leq$ -20°F have occurred from early November to early April but are most likely in January and February. While the probability on any given day of experiencing such intense cold never exceeds 0.10, for the winter as a whole temperatures below -20°F occur every year and temperatures $\leq$ -40°F occur about one year in eight. In the absence of snowcover, these cold temperatures can lead to winterkill of tender plants.

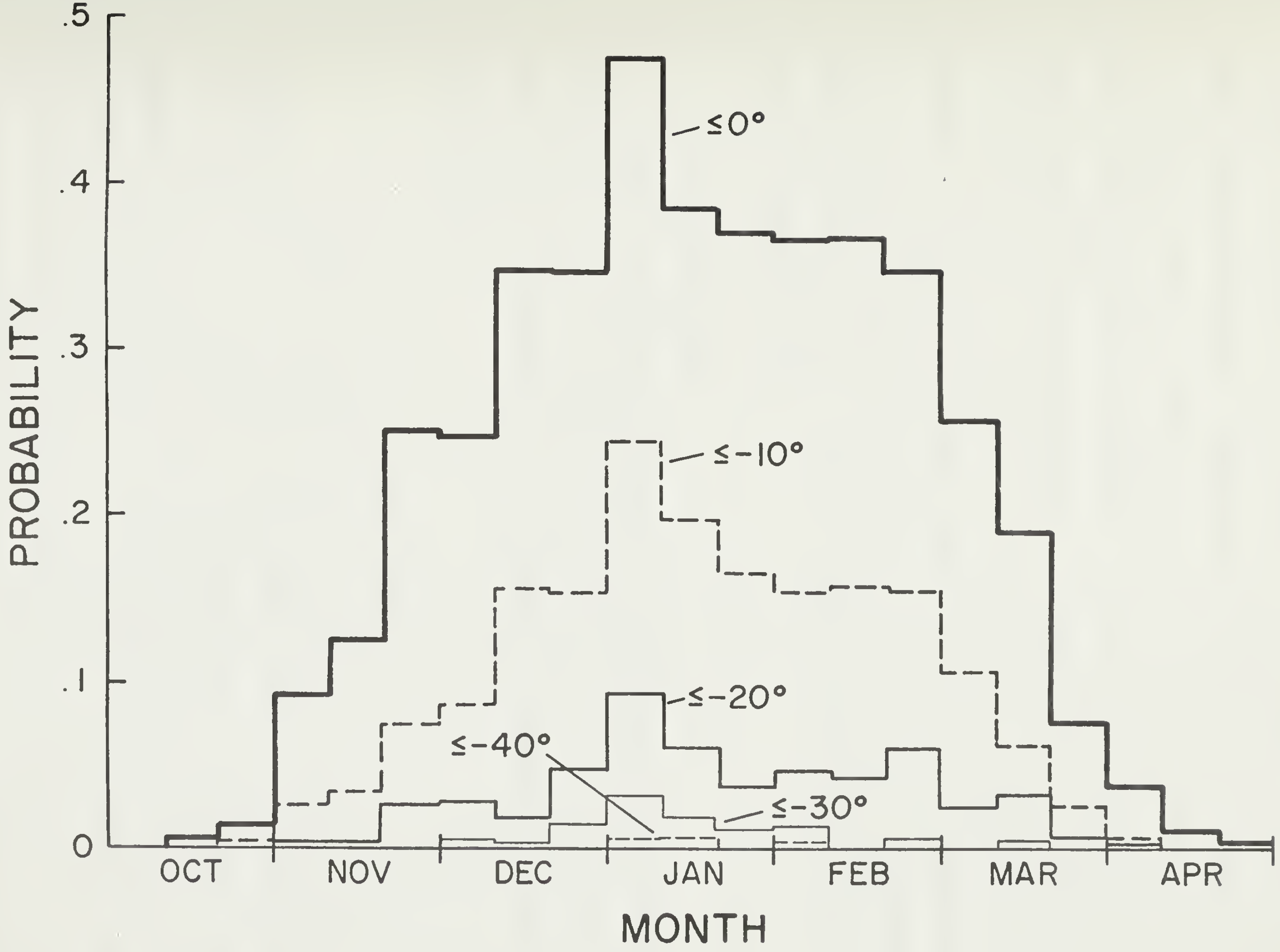


Figure 13. Probability of daily minimum temperature dropping to a) ≤ 0°F, b) ≤ -10°F, c) ≤ -20°F, d) ≤ -30°F, and e) ≤ -40°F. Probabilities averaged over one-third month intervals at Walden, Colorado, 1938-1980.

Probabilities of experiencing daily summer temperatures above various warm thresholds are shown in Figure 14. Extreme heat is not a problem in North Park, but temperatures above 75°F occur regularly from June through September. Temperatures in excess of 85°F occur relatively infrequently (maximum probability of only .05) and are most likely in mid to late July and early August. These warm temperature extremes are not a severe hazard by themselves, but they do lead to rapid drying of topsoil and can contribute to moisture stress, especially in young plants. The period of highest probability of very warm temperatures thus must be accompanied by adequate precipitation (or supplemental water must be applied) in order to assure survival of new plant life on the reclamation site.

2) Precipitation

Several aspects of precipitation in North Park are described here. Emphasis is placed on areal distribution and seasonal variations of total precipitation along with frequency and intensity of heavy rain and snow events.

a) McCallum site precipitation

The Walden weather station is the only long-term precipitation station near to the McCallum Study Area. However, the McCallum site is much closer to the Medicine Bow Mountains east of North Park. The U.S. Weather Bureau analyses of North Park precipitation (Figures 4 and 7) estimated annual precipitation for the McCallum site to be 16 inches with 6 to 8 inches of this total falling during the winter months (October through April) and the remaining 8 to 10 inches occurring during the summer. These totals are considerably higher than the

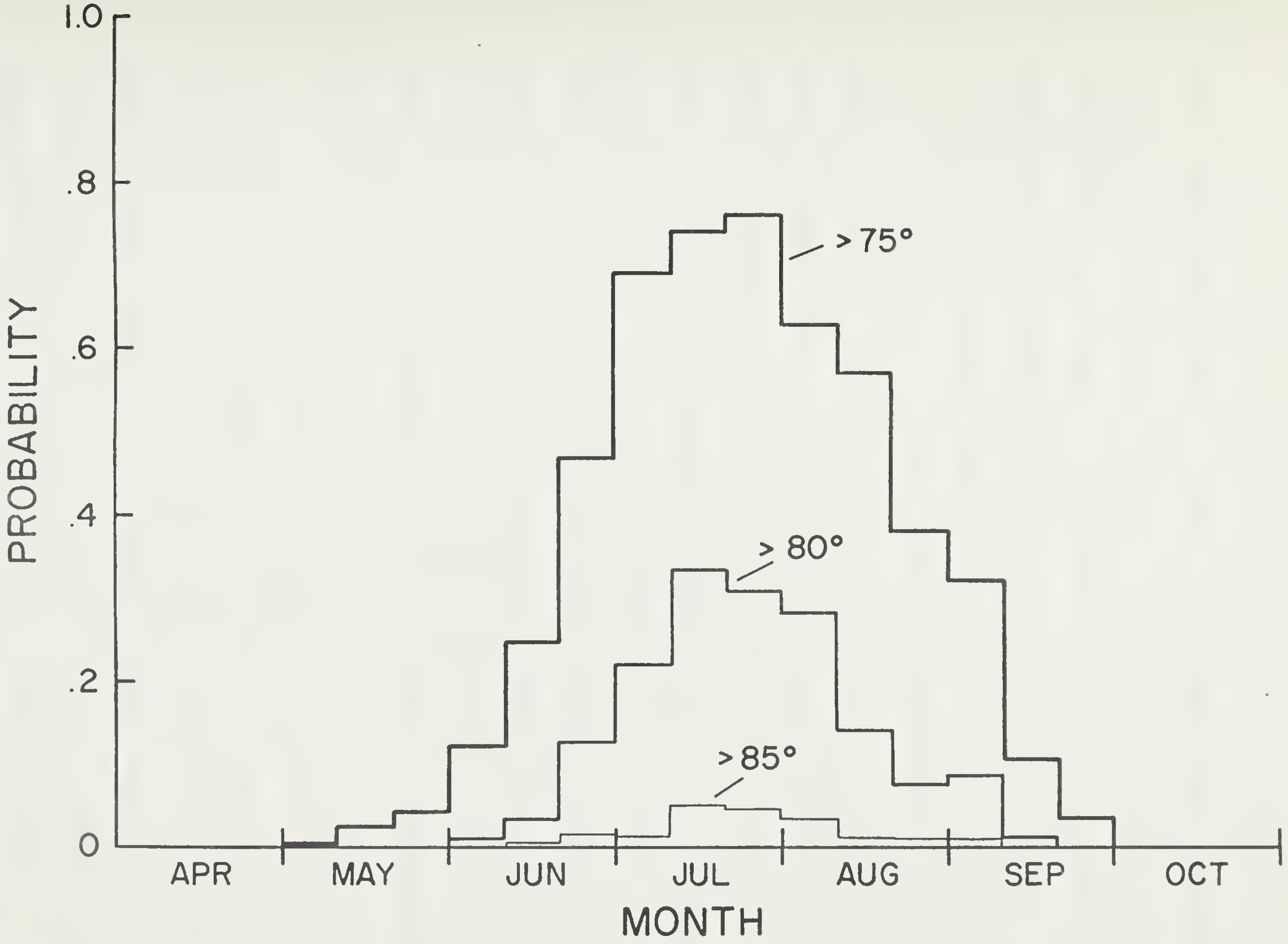


Figure 14. Probability of daily maximum temperature exceeding a) 75°F, b) 80°F, and c) 85°F. Probabilities averaged over one-third month intervals at Walden, Colorado, 1937-1980.

measured 9.67 inch annual average at Walden (4.18 inches in winter, 5.49 inches in summer).

Both the map analyses and a detailed computer model of mountain precipitation (Rhea, 1978) indicate a significant winter precipitation increase from Walden to the McCallum site. However, significant vegetative changes do not appear, and eyewitness reports from people who frequently drive from Walden eastward suggest that significant increases in snowfall are not observed until just east of the McCallum site.

Data to confirm or refute these interpretations are just becoming available as two U.S. Geological Survey stations on the McCallum Study Area have began year-round data collection. Data from the first winter (1979-80, a wetter than average winter in North Park) showed no difference in precipitation from Walden eastward to the site. But lower gage catch ratios at the exposed windswept U.S.G.S. sites seemed likely. Over a long period it appears that a good estimate of winter precipitation at the McCallum site would be about 5 inches with slightly lower values occurring at the extreme western edge of the area with precipitation increasing to perhaps 6 inches on the eastern and northeastern edges of the area.

The conclusion that average summer precipitation is quite uniform across the park appears to be accurate. However, map values (Figure 7) are distinctly too high. Data from available stations indicate summer averages ranging from 5.49 inches at Walden and 6.41 inches at Spicer to 8.36 inches at Gould. A good estimate for average summer precipitation at the McCallum site is about 6 inches.

Combining estimates for winter and summer precipitation, average annual precipitation at the McCallum site is approximately

11 to 12 inches. Additional data collected on the site in the months and years to come will help evaluate this estimate.

b) annual and seasonal variability

Considerable year to year variability of both annual and seasonal precipitation occurs. This is highly significant in terms of both vegetation selection and assessment of potential success for reclamation strategies.

A probability distribution of both annual and seasonal precipitation for Walden is shown in Figure 15. (Adjustments to these curves could be made to reflect the expected differences in average precipitation between Walden and the McCallum Study Area.) Winter precipitation at Walden has ranged from 1.91 to 6.94 inches with a median value of 4.12. Fifty percent of the years the winter precipitation remains within one inch of the median.

The shape of the distribution of summer precipitation is similar to winter except near both ends of the distribution. This is because greater extremes relative to the median value occur during the summer. Summer totals have ranged from 2.40 to 10.18 inches with a median value of 4.91. Sixty percent of all summers receive less than the average precipitation.

Since vegetation is limited by the driest years and seasons, it is important to examine the low ends of each distribution. Summer precipitation at Walden less than 3.50 inches occurs about one year in ten. In winter, one year in ten receives less than 2.60 inches of precipitation. Plants chosen for revegetation must be able to tolerate these extreme conditions.

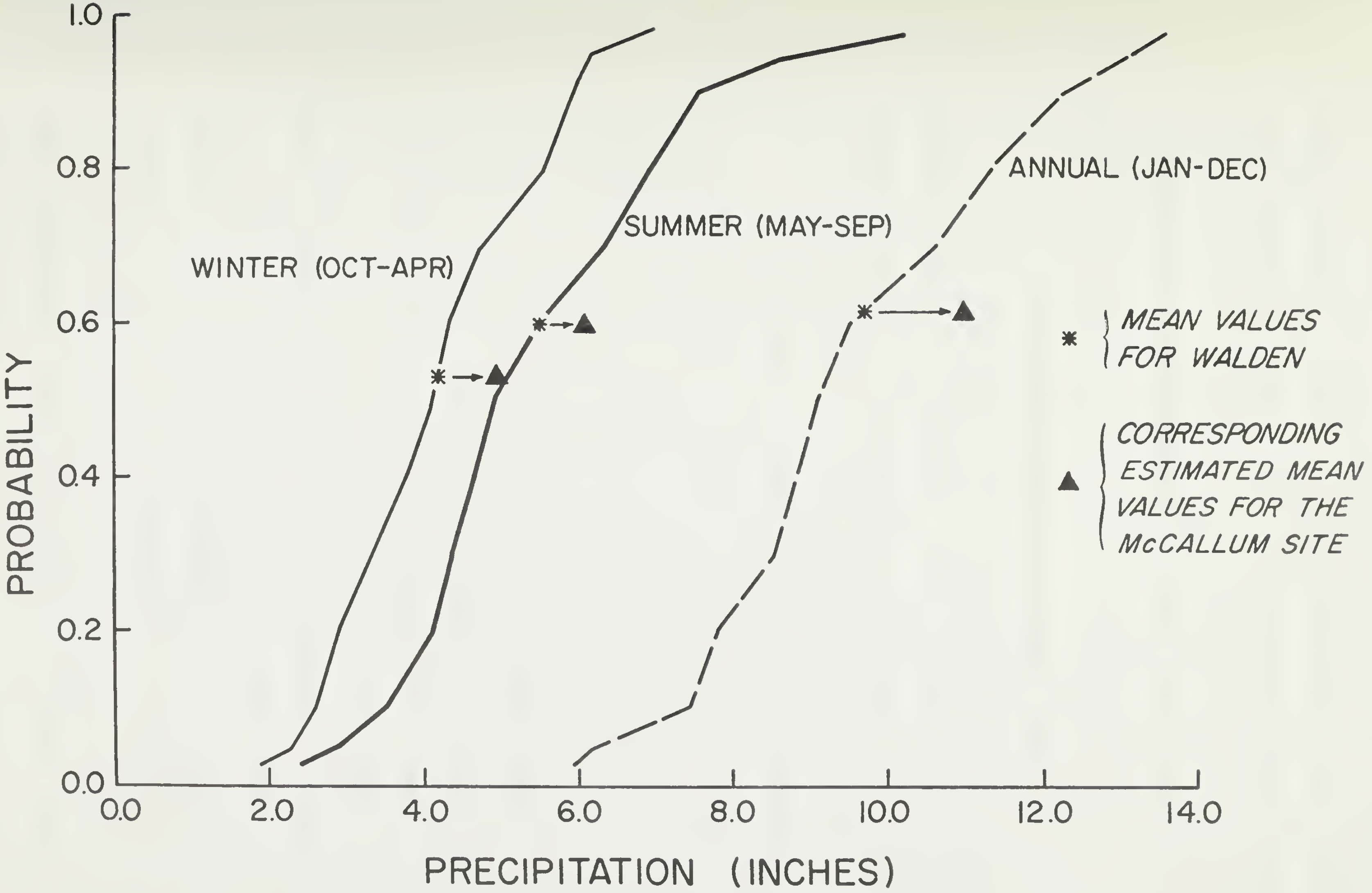


Figure 15. Probability of receiving X inches or less of precipitation during winter, summer, and annually at Walden, Colorado, 1938-1980. Mean seasonal and annual values for Walden are shown along with estimated mean values for the McCallum site.

Some plants can survive water shortages but require considerably more water to initially become established. Hence, there are only certain years when these plants can naturally germinate and become established. For example, if a plant species requires at least 7 inches of summer season precipitation to become established, the local climate will meet these demands only one year in five.

c) frequency and intensity probabilities

The number and size of precipitation events are important in various aspects of reclamation. Since the only long-term precipitation records available in North Park are daily totals, this discussion is limited to precipitation events defined as 24-hour amounts.

The frequency and intensity of daily precipitation for a yearly period are presented in Figure 16. The ordinate is probability and the abcissa is number of days, N. Individual points on the graph are the probability that a given year will have less than N days with precipitation greater than X where X is the threshold value of precipitation for each separate line on the graph. The graph shows that for a threshold of 1.00 inches there is a 77% probability that no days will occur with greater than 1.00 inches of precipitation. There is a 98% probability that no more than 1 day will occur with greater than 1.00 inches of precipitation. It is not until the threshold is lowered to 0.20 inches that a significant number of days appear. The median (50%) number of days with precipitation equalling or exceeding 0.20 inches is about 20. There is a 10% chance that only 15 days will occur and only a 10% chance that more than 27 will occur. Thus, 80% of the years will have between 15 and 27 days with precipitation equal to or greater than 0.20 inches.

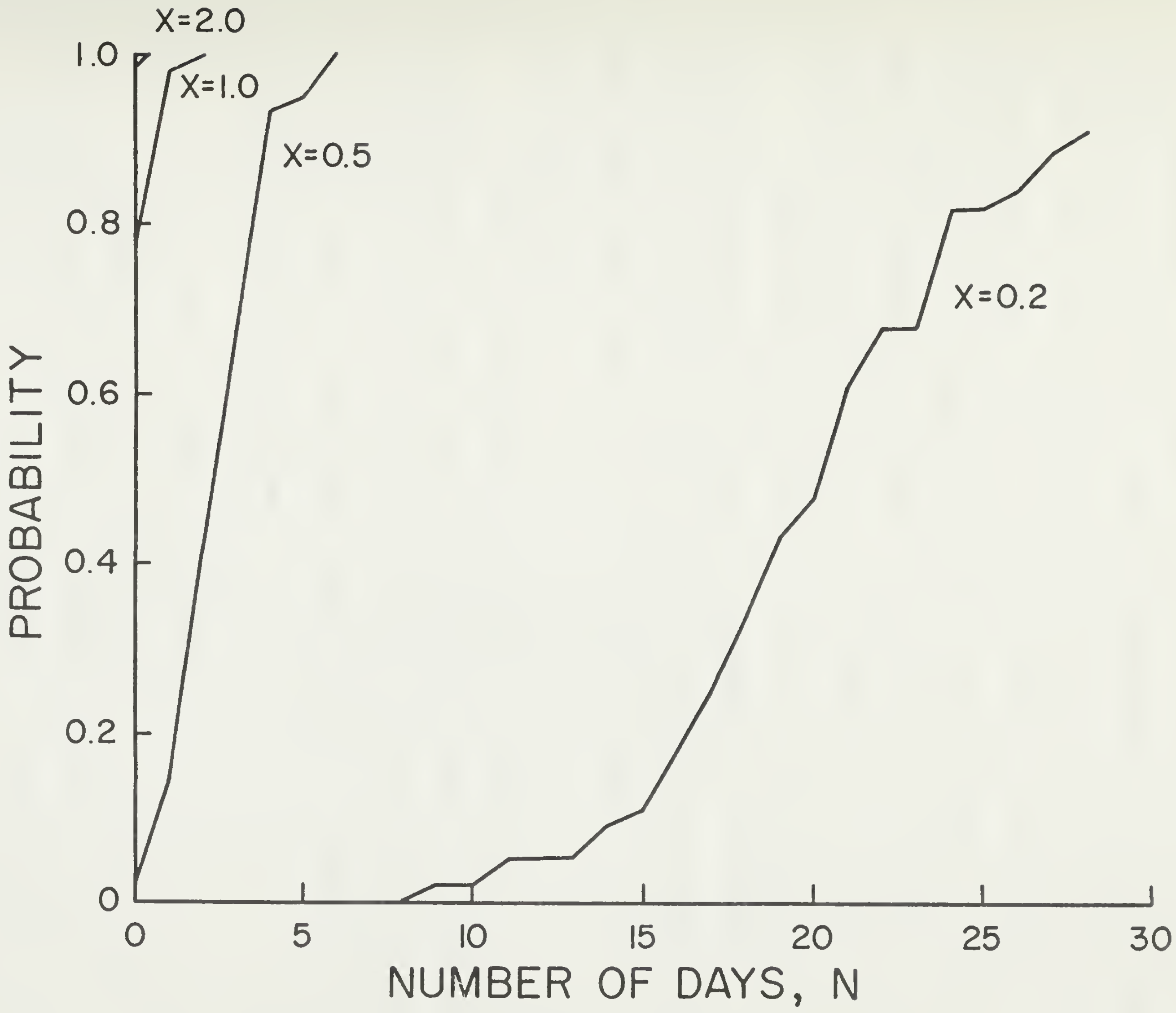


Figure 16. Probability that year has N days or less of precipitation equal to or greater than X inches for Walden, Colorado, 1938-1979.

The implication of this graph for successful revegetation is striking. Significant precipitation events are required to substantially contribute to soil moisture content. But in dry years daily precipitation totals of 0.50 inches or greater may occur only one time or less. This would place severe moisture stress on young plants. In wetter years as many as four or five occurrences of precipitation events equalling or exceeding 0.50 inches can be expected. In such years, the likelihood for establishing vegetation is much higher. Typically 3 or less large storms ($\geq$ 0.50 inches) occur in a year.

These data indicate that the climate is so dry that it is likely that more than one attempt to revegetate will be required. Mulching, increasing the depth of topsoil, and/or providing supplemental water would significantly raise the chances of revegetation success on the first attempt.

The second implication from Figure 16 is that large rain events capable of causing major erosion problems rarely occur. The low probabilities for 0.50 and 1.00 inch precipitation events have already been described. There is a 98% chance that no one-day rain greater than 2 inches will occur in a given year.

d) snowfall frequency and intensity

Probability of daily snowfall at Walden is shown in Figure 17 in a form identical to Figure 16. The only difference is that the X threshold values are in inches of snowfall. An immediate conclusion is that large daily snowfalls are very rare. In fact, a 6-inch daily snowfall has only occurred a maximum of 3 times in one winter. There is a 41% chance that a 6-inch daily snowfall will not occur at all. Figure 18 shows the same information for snowstorms instead of daily snowfall.

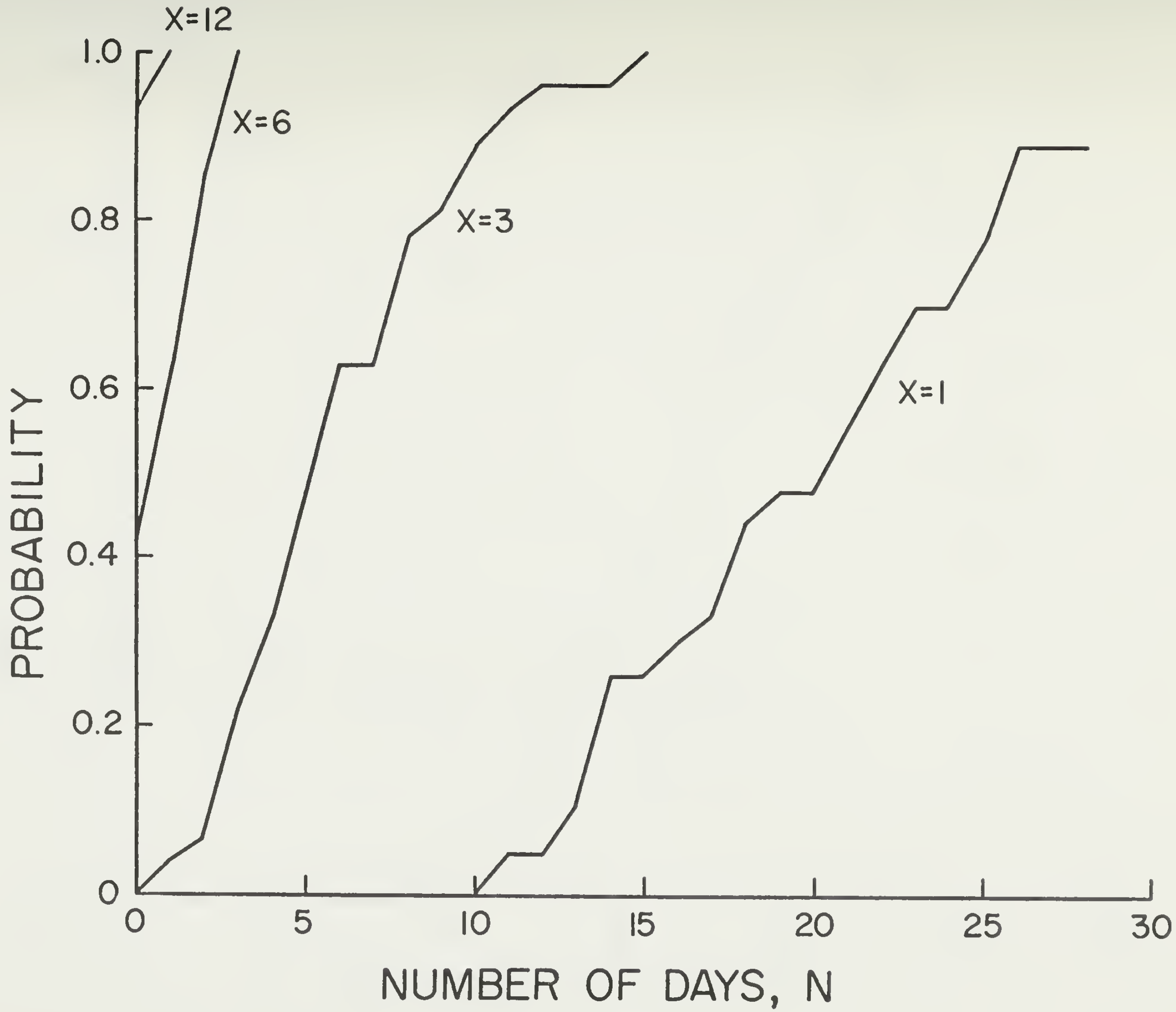


Figure 17. Probability that a winter season has N days or less of snowfall equal to or greater than X inches for Walden, Colorado, 1938-1980.

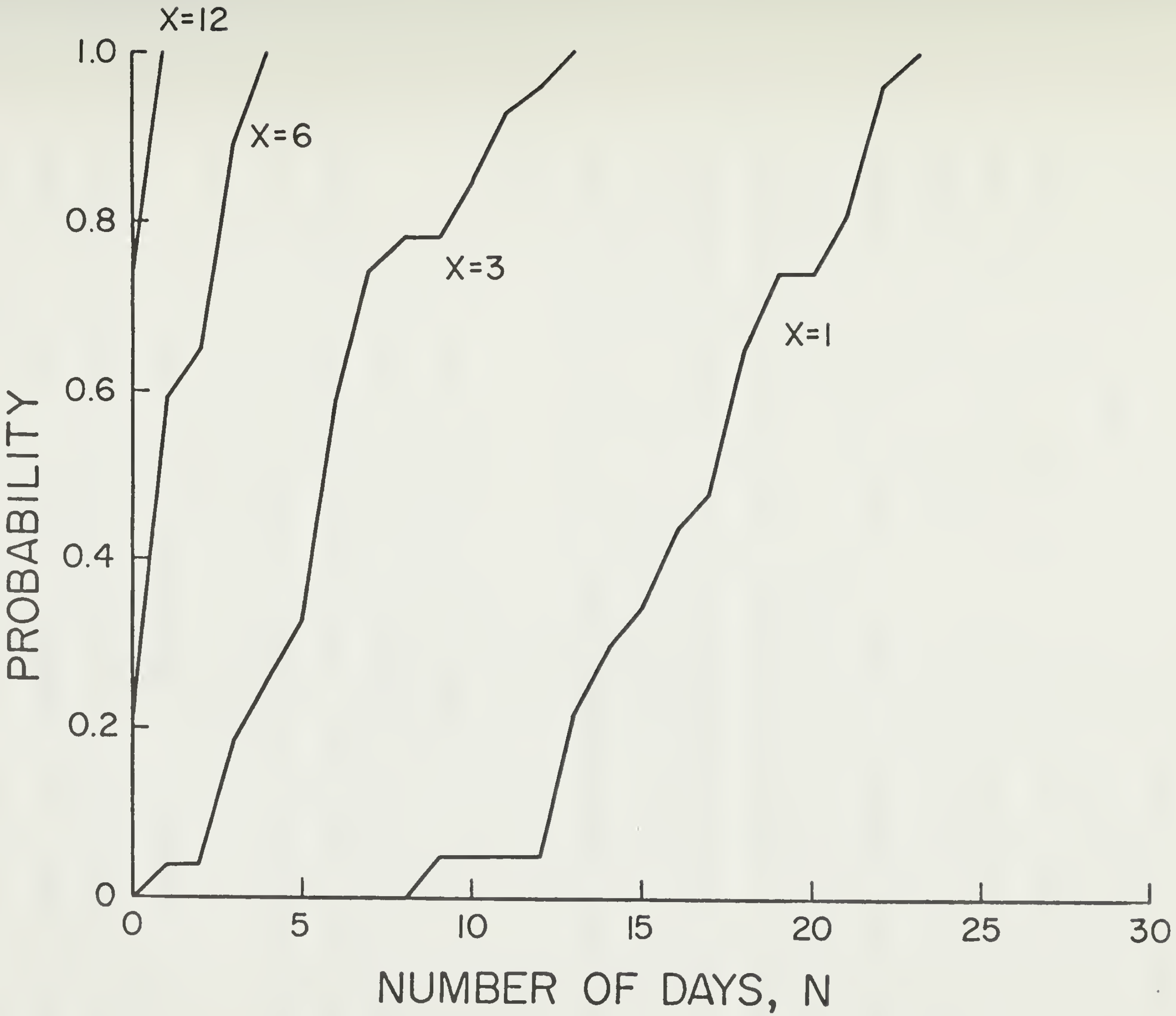


Figure 18. Probability that a winter season has N storms or less of snowfall equal to or greater than X inches for Walden, Colorado, 1938-1980.

A snowstorm is defined as the snowfall total for all consecutive days when daily snowfall equals or exceeds 1 inch. The change of definition has a small but noticeable effect on probabilities. For example, there is only a 22% chance of not getting a 6-inch storm in a given winter, and there have been as many as four 6-inch storms in one winter.

These snowfall statistics require some modification for use on the McCallum site. Since winter precipitation is likely to be higher than at Walden by about 15 to 25%, both the number and size of storms are probably increased. Without data it is difficult to make any confident estimates of these differences. However, the general conclusions are the same. Snowfall is not excessive and can be very light in some years. Because single storm snowfall totals are not large, driving conditions and mobility should not be greatly restricted by snowfall alone throughout the winter. By far the worst problems will be caused by blowing and drifting of the existing snow by the strong winds which buffet the area.

e) snow accumulation and snowmelt

The amount of snow on the ground during the winter months is significant from several perspectives. Snow affects surface mobility, acts as an insulating blanket to protect plants from extreme cold, and contributes to the soil moisture as it melts.

The probability of having snow on the ground on any given day at Walden exceeding the thresholds of 0, 4, and 10 inches is shown in Figure 19. (Again, it should be remembered that somewhat greater snowfall, and hence snowdepth, is expected at the McCallum site compared to Walden.) Measurable snow may stay on the ground anytime from September

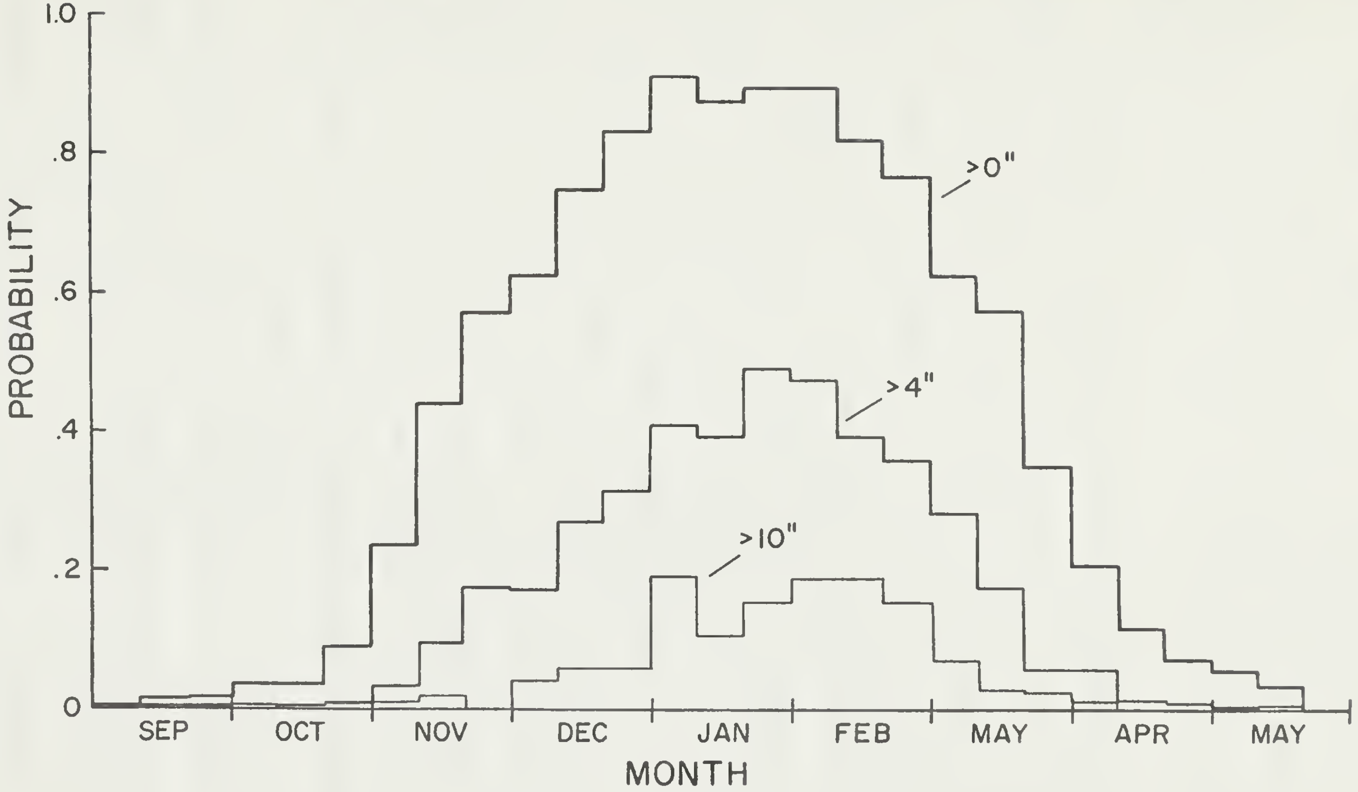


Figure 19. Probability of having snowdepth on the ground exceeding a) 0 inches, b) 4 inches, and c) 10 inches. Probabilities averaged over one-third month intervals at Walden, Colorado, 1938-1980.

through May. From late November until mid-May there is a greater than 50 percent probability that at least an inch of snow will be on the ground on any given day. However, even in midwinter when temperatures tend to be coldest, there is a one in ten chance that the ground will be bare. This implies that there is a good chance that very cold temperatures will occur when there is little snow on the ground to protect vegetation.

Snowdepths in excess of 4 inches at Walden never achieve a probability in excess of 0.50. Four inches is not a lot of snow and when the windy conditions of North Park are considered, which can easily blow the snow off of exposed areas, it would be reasonable to expect many times during the winter when smooth exposed surfaces may be free of snow. As a result, topsoil erosion as well as winterkill of plants may be a problem. Increasing surface roughness and/or constructing snowfences may be required to reduce these problems.

There can be extreme variability of snowdepth throughout the winter and from one year to the next. The most likely periods to experience deep snow are in early January and again during late January and most of February. However, the probability of having more than 10 inches of snow on the ground on any given day never exceeds 0.20.

The period of maximum snowmelt in the Walden-McCallum area occurs during March. (Note the rapid decrease in snowdepth probabilities on Figure 19.) This has a bearing on surface moisture, trafficability and erosion. Extremely muddy conditions can be expected until well into April and May following wet winters. However, the water content of the snowpack is generally not excessive. Daytime temperatures during March and April rise above freezing regularly but nighttime temperatures almost

always fall back below freezing. As a result, the rate of snowmelt is retarded and significant erosion is usually not a problem.

f) large rain events--return periods

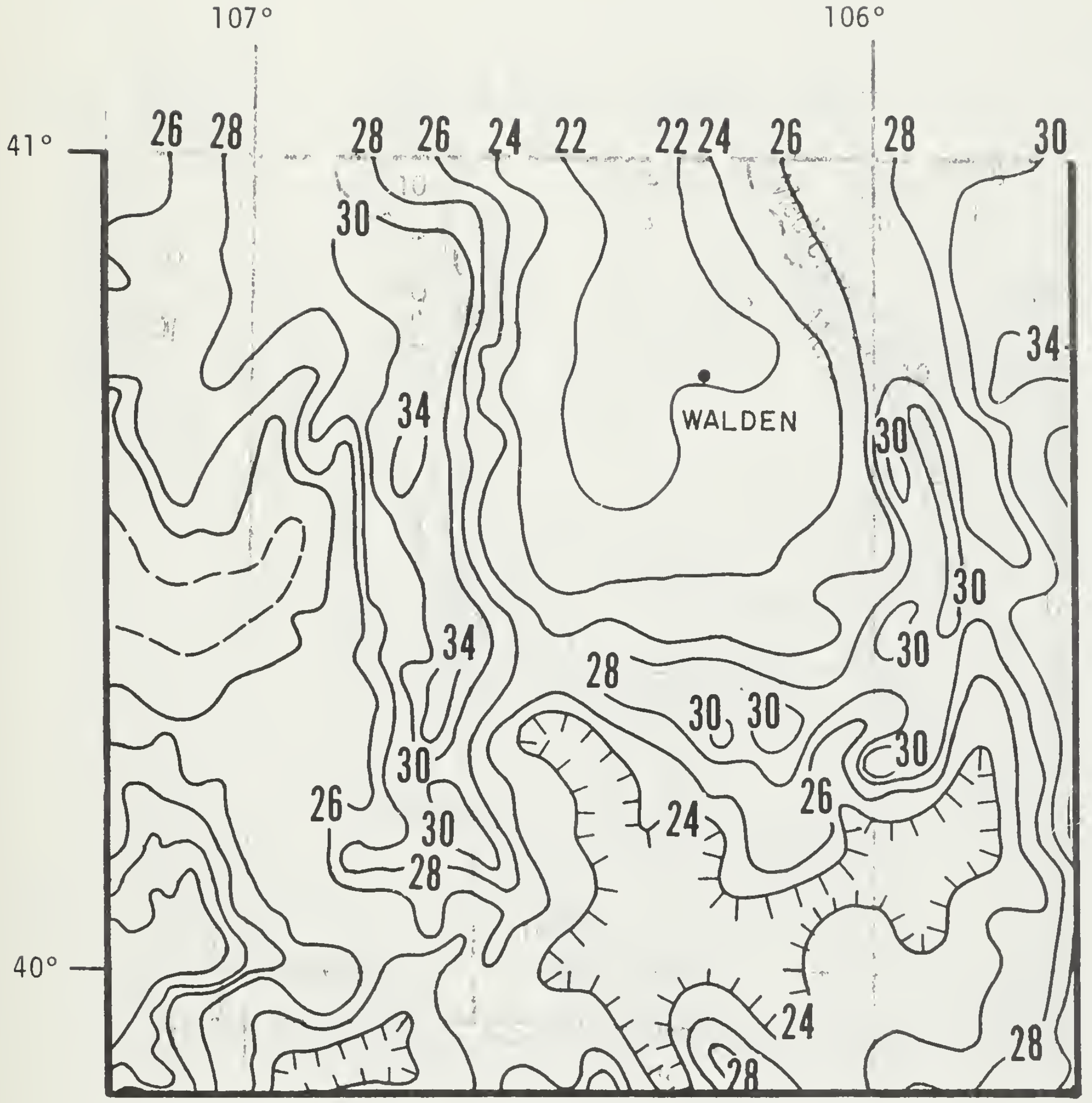
A commonly used parameter for consideration of road construction and erosion is the return period precipitation which is a measure of the probability of large rain events. Figures 20 and 21 show the 50-year and 100-year 24-hour return period precipitation for the North Park area (Miller, Frederick, and Tracey, 1973). The values are between 2.2 inches and 2.4 inches for 50 year return periods and between 2.4 inches and 2.6 inches for 100 year return periods. These values are consistent with the frequency data shown in Figure 16. The basic reason for such small return period amounts is that the elevation of the site and the mountains shielding the area from east, south, and west severely limit the amount of water available for precipitation. As a result the convective storms of summer are usually rather light in total amounts of rain.

3) Joint Analyses of Temperature and Precipitation

Plants respond not solely to temperature or precipitation, but to a combination of all climatic elements.

a) growing season--joint probability

The potential thermal growing season is "potential" in that active plant growth could potentially occur during this period if soil water were continuously available. To calculate the occurrence of favorable periods of both air temperature and soil water would require determining a complete soil water balance. Unfortunately, the necessary data are unavailable for virtually all revegetation sites. However, rainfall



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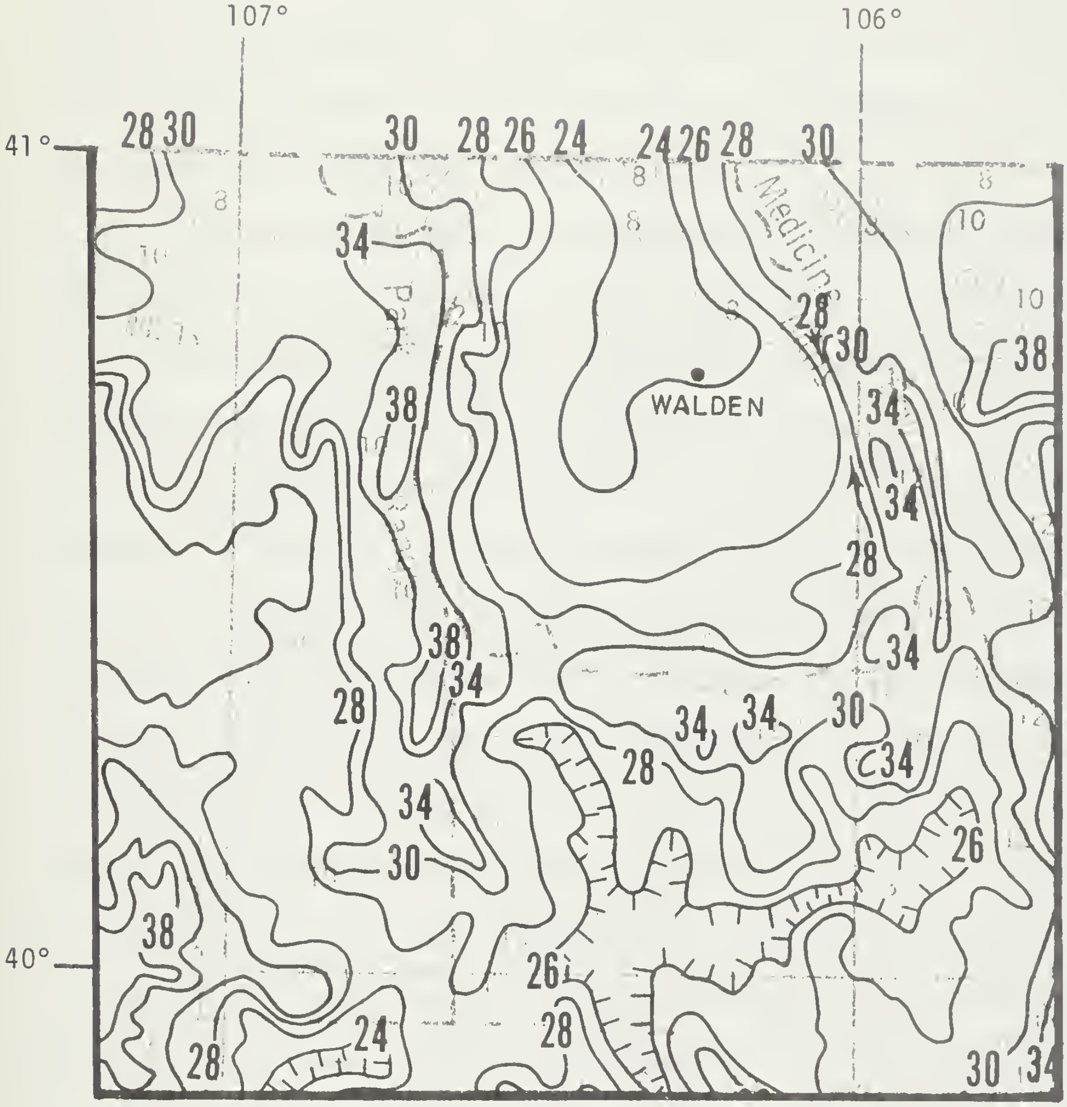
Soil Conservation Service, Engineering Division

Figure 20. Isopluvials of 50-year 24-hour precipitation (in tenths of an inch) for north central Colorado.



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National Oceanic and Atmospheric Administration
National Weather Service, Office of Hydrology
Prepared for U.S. Department of Agriculture,
Soil Conservation Service, Engineering Division

Figure 21. Isopluvials of 100-year 24-hour precipitation (in tenths of an inch) for north central Colorado.

amounts above a reasonable threshold over a period of a few days can be used as a surrogate for the soil water balance of the surface layer. Once the probabilities of the rainfall amount above a given threshold for a given time period are determined, the joint probability of both air temperature and rainfall can be calculated.

For the Walden data the probability of at least 0.20 inches of rain occurring within a 3-day period was calculated. The threshold of 0.20 inches and the 3-day period were used to represent the minimum requirements for growth for newly established plants.

Figure 22 illustrates the joint probability of at least 0.20 inches of rain within a 3-day period and a 7-day end-element running mean air temperature above 40°F (potential thermal growing season). The potential thermal growing season influences the joint temperature-rainfall probability for the first 45 days in the spring and the last 50 days in the fall. Between the first of June and mid-September, the rainfall probability alone determines opportunities for active growth. As temperatures warm in the spring the joint probability gradually rises to above 0.20 in early June. The joint probability then decreases from about the first week in June to a minimum in the first week in July but again increases to a high in the last week in July. Thereafter, the joint probability erratically decreases until temperature again becomes the primary control.

The joint probability analysis has direct implications for plant growth and survival. Although the exact significance of probability thresholds are not known, some periods are clearly better suited for plant growth than others. For example, if one examines the 0.25 joint probability level across the graph, 4 short periods occur that

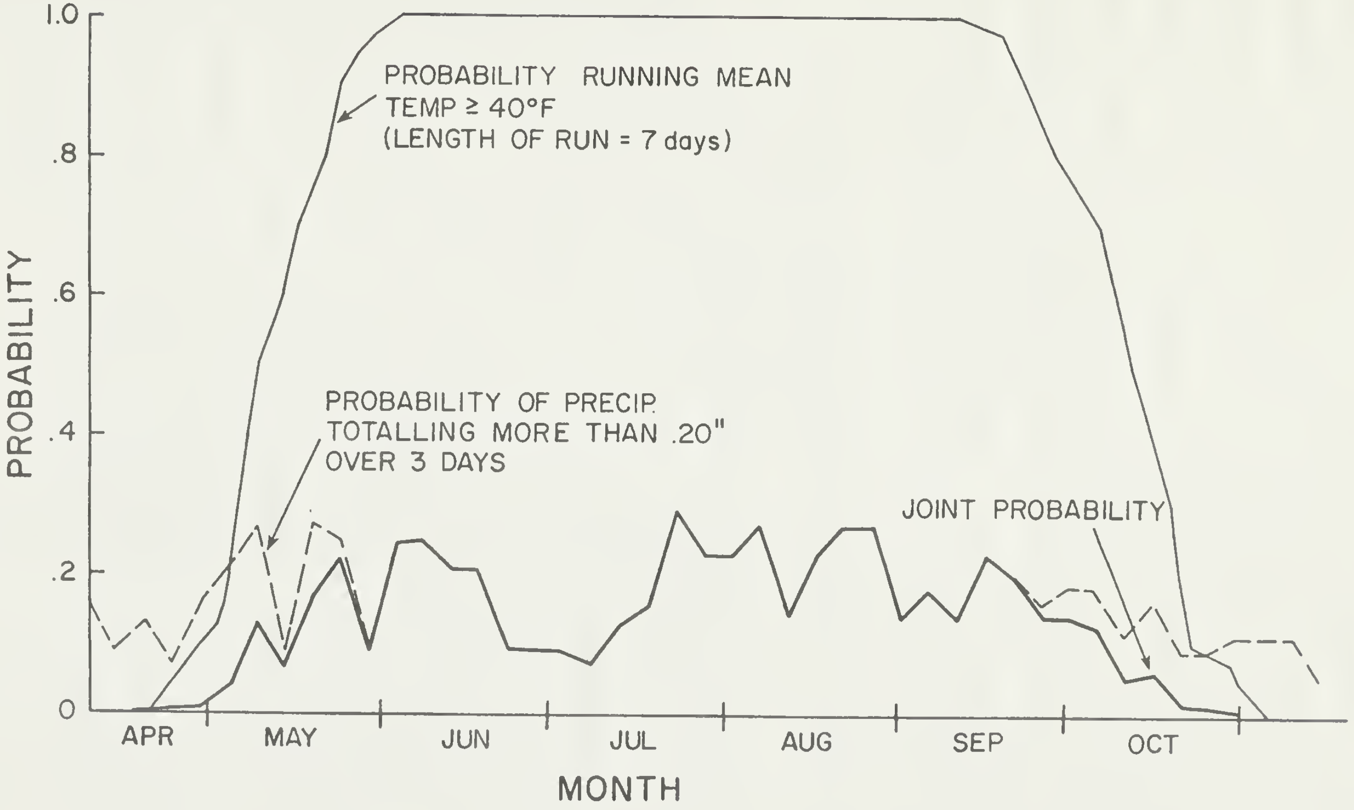

Figure 22. Probability of receiving significant precipitation during the growing season at Walden, Colorado, 1938-1979. Thin solid curve is the probability of being in the thermal growing season. Dashed curve is the probability of receiving more than 0.2" precipitation in 3 days. Thick solid curves are the joint probability of the other two curves.

might be especially favorable for active growth once every 4 years. Considering the 0.10 (1 year in 10) joint probability level, two long periods favorable for active growth can be expected. However, note the low probability for rain between late June and early July. This dip in the joint probability suggests a low survival rate for new vegetation without the help of irrigation during this high-stress period. This example serves to illustrate the uncertainties of favorable periods for active growth. The probabilities are average and bear no significance for any individual year of interest. The joint probability simply illustrates the harsh conditions that newly established plants would encounter.

b) growing season potential evapotranspiration minus total precipitation

Potential evapotranspiration at Walden (calculated by the Blaney-Criddle method; Toy, 1979) is approximately 23 inches between April and September as seen in Figure 23. The average rainfall for the same period is about 7 inches which results in a moisture deficit of 16 inches. Figure 23 dramatically illustrates the awesome limitations for optimum growth on revegetated sites near Walden. This, however, is not of direct practical use since water deficits calculated from potential evapotranspiration estimates apply only when the concern is for optimum conditions for maximum production. This high level of production need not be reached since regulations only require revegetation sites to be restored to production levels equivalent to native plant productivity.

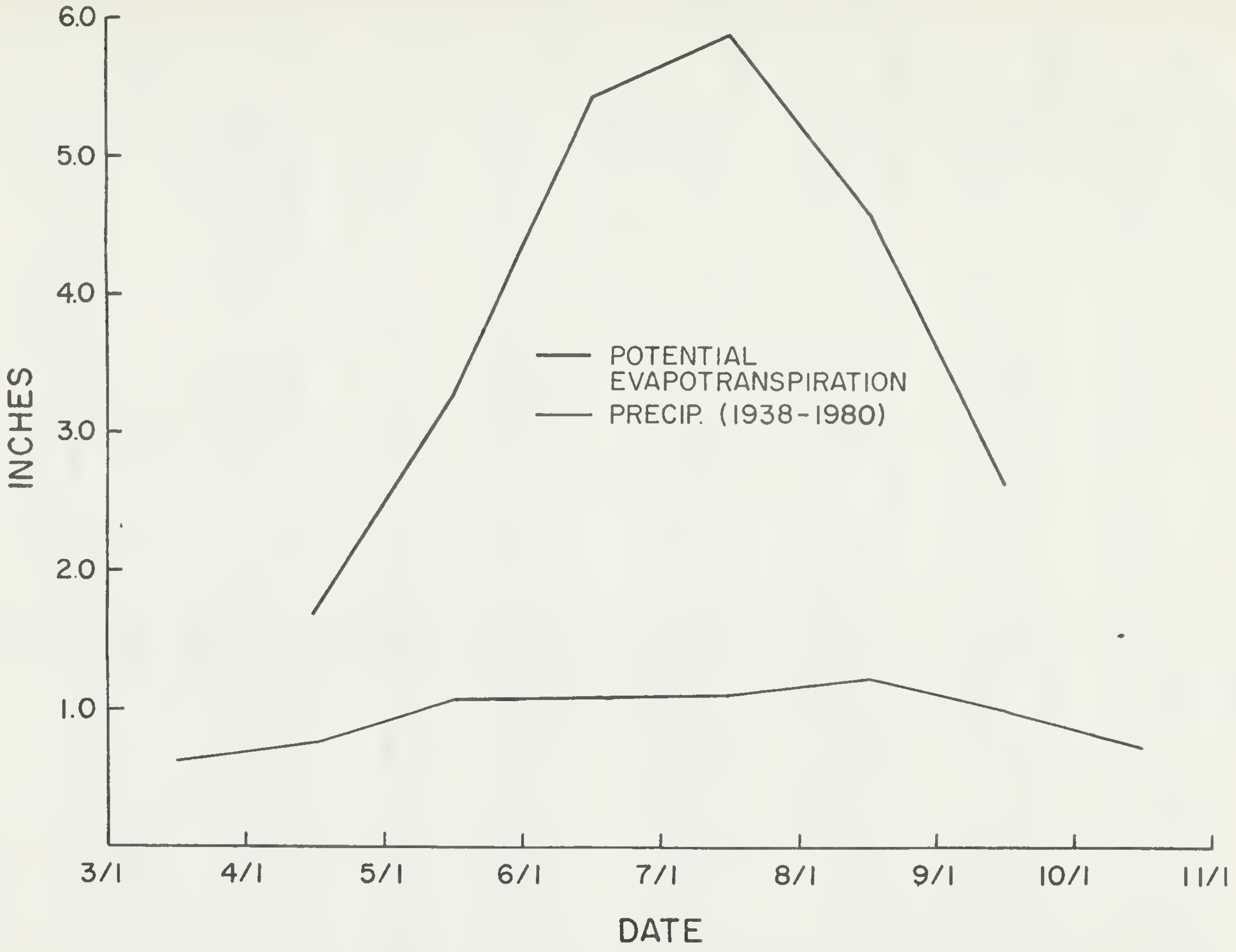

Figure 23. Monthly evapotranspiration (calculated by the Blaney-Criddle method) and average monthly precipitation for Walden, Colorado, 1938-1980.

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VII. APPENDIX

Period of record monthly climatic summaries of temperature and precipitation for North Park weather stations at Walden and Spicer.

SUMMARY OF MONTHLY CLIMATIC DATA FOR WALDEN COLORADO LAST DATA 12/1978 SUBSTATION NO. 58756
PREPARED BY THE COLORADO CLIMATE CENTER, DEPARTMENT OF ATMOSPHERIC SCIENCE, COLORADO STATE UNIV., FT. COLLINS, CO 80523
LONGITUDE - 10616 LATITUDE - 4044 ELEVATION - 8099

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MONTHLY PRECIPITATION (IN)	AVE.	.52	.42	.58	.77	1.08	1.03	1.14	1.22	1.03	.72	.56	.55	9.51
	MAX.	1.38	1.46	1.35	1.83	3.16	3.04	3.06	2.99	3.75	2.09	1.91	2.40	13.56
	YEAR	1969	1971	1938	1968	1978	1969	1956	1963	1961	1951	1973	1951	1951
	MIN.	.08	.03	.12	.05	.05	.03	.12	.12	0.00	0.00	0.00	.08	5.92
	YEAR	1965	1973	1962	1952	1974	1950	1962	1942	1956	1956	1949	1946	1964
	YEARS OF RECORD	39.	40.	40.	40.	40.	41.	41.	41.	40.	40.	40.	40.	38.
GREATEST DAILY PRECIP (IN)	AMOUNT	.63	.40	.50	.78	1.63	1.16	2.19	.86	.96	.83	1.03	.90	
	YEAR AND DAY	197102	197111	197507	195028	197817	196917	195228	195102	196122	196603	197303	195130	
	YEARS OF RECORD	30,	29.	30.	30.	31.	31.	31.	31.	30.	30.	30.	30.	
MONTHLY SNOWFALL (IN)	AVE.	7.7	6.3	7.9	6.4	3.2	.5	0.0	0.0	1.3	3.2	7.3	8.0	51.0
	MAX.	22.0	20.0	23.4	19.5	19.7	12.0	0.0	0.0	21.5	12.0	26.5	31.0	84.1
	YEAR	1969	1971	1938	1968	1978	1974	1938	1938	1961	1970	1973	1951	1973
	MIN.	1.2	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	22.6
	YEAR	1965	1973	1968	1954	1974	1978	1978	1978	1975	1954	1949	1946	1963
	YEARS OF RECORD	39.	35.	38.	40.	40.	41.	41.	41.	39.	39.	37.	40.	30.
GRTST DEPTH SNOW ON GRND IN MON (IN)		33	31	19	13	9	8	0	0	7	8	25	32	
	YEAR AND DAY	194910+	194915	195202+	195201	197817	197408	0	0	197819	197524+	197304	195131	
	YEARS OF RECORD	30.	30.	29.	25.	19.	29.	31.	31.	29.	25.	30.	30.	
NO DAYS PRECIP GTR OR EQ 0.1 IN	AVE.	3.1	2.3	2.8	3.1	4.2	3.4	4.3	5.4	4.0	2.7	2.7	2.9	41.8
	MAX.	9	7	12	11	13	13	11	16	11	10	7	10	104
	YEAR	1951	1952	1952	1951	1952	1951	1953	1951	1961	1951	1951	1951	1951
	MIN.	0	0	0	0	0	0	0	1	0	0	0	0	21
	YEAR	1978	1973	1962	1959	1974	1977	1962	1974	1956	1971	1974	1974	1954
	YEARS OF RECORD	30.	29.	30.	30.	30.	31.	31.	31.	30.	30.	30.	30.	28.
NO DAYS PRECIP GTR OR EQ 0.5 IN	AVE.	.1	.0	.1	.1	.4	.4	.6	.4	.4	.4	.1	.2	3.3
	MAX.	1	1	2	1	2	2	3	2	2	2	1	3	11
	YEAR	1971	1948	1949	1971	1957	1957	1956	1977	1965	1969	1973	1948	1948
	MIN.	0	0	0	0	0	0	0	0	0	0	0	0	0
	YEAR	1978	1978	1978	1978	1975	1978	1978	1978	1975	1978	1978	1978	1964
	YEARS OF RECORD	29.	29.	29.	29.	30.	30.	30.	30.	29.	29.	29.	29.	28.
NO DAYS PRECIP GTR OR EQ 1.0 IN	AVE.	0.0	0.0	0.0	0.0	.1	.1	.1	0.0	0.0	0.0	.0	0.0	.3
	MAX.	0	0	0	0	1	1	1	0	0	0	1	0	1
	YEAR	1948	1948	1948	1948	1978	1970	1959	1948	1948	1948	1973	1948	1978
	MIN.	0	0	0	0	0	0	0	0	0	0	0	0	0
	YEAR	1978	1978	1978	1978	1976	1978	1978	1978	1978	1978	1978	1978	1975
	YEARS OF RECORD	29.	29.	29.	29.	30.	30.	30.	30.	29.	29.	29.	29.	28.
NUMBER OF DAYS WITH HAIL	AVE.	0.0	0.0	0.0	0.0	.1	.1	.2	.0	0.0	0.0	0.0	0.0	.4
	MAX.	0	0	0	0	1	1	2	1	0	0	0	0	2
	YEAR	1955	1956	1956	1956	1976	1970	1973	1977	1956	1956	1956	1956	1973
	MIN.	0	0	0	0	0	0	0	0	0	0	0	0	0
	YEAR	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978
	YEARS OF RECORD	22.	22.	22.	22.	23.	23.	23.	23.	22.	22.	22.	22.	21.
NO. OF DAYS WITH SNOW ON GROUND (GTR OR EQ 1 INCH ON GROUND)	AVE.	28.5	23.2	13.8	3.2	.3	0.0	0.0	0.0	.5	2.3	10.7	25.8	107.6
	MAX.	31	29	29	10	3	0	0	0	3	12	19	31	144
	YEAR	1978	1958	1964	1968	1978	1963	1963	1963	1965	1969	1964	1978	1964
	MIN.	7	7	1	0	0	0	0	0	0	0	1	10	52
	YEAR	1965	1976	1972	1978	1976	1978	1978	1978	1977	1978	1974	1969	1966
	YEARS OF RECORD	15.	15.	13.	13.	15.	15.	16.	16.	15.	15.	15.	12.	9.

Monthly Precipitation Summary for Walden, Colorado, 1938-1978.

SUMMARY OF MONTHLY CLIMATIC DATA FOR WALDEN COLORADO LAST DATA 12/1978 SUBSTATION NO. 58756
PREPARED BY THE COLORADO CLIMATE CENTER, DEPARTMENT OF ATMOSPHERIC SCIENCE, COLORADO STATE UNIV., FT. COLLINS, CO 80523
LONGITUDE - 10616 LATITUDE - 4044 ELEVATION - 8099

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MONTHLY MEAN MAXIMUM TEMP (F)	AVE.	27.7	30.9	37.1	49.4	60.8	70.5	77.8	75.4	67.9	56.7	40.0	30.9	52.1
	MAX.	35.2	40.8	46.5	58.7	66.9	77.7	81.5	80.0	72.8	64.5	51.8	41.3	54.9
	YEAR	1954	1954	1972	1943	1969	1977	1966	1969	1956	1950	1949	1950	1954
	MIN.	19.1	20.4	26.5	41.6	55.3	64.0	73.9	70.2	58.2	44.5	30.4	24.2	49.5
	YEAR	1949	1939	1965	1973	1953	1951	1950	1968	1961	1969	1938	1978	1973
YEARS OF RECORD		39.	40.	40.	40.	41.	41.	41.	41.	40.	40.	40.	40.	36.
MONTHLY MEAN MINIMUM TEMP (F)	AVE.	3.3	5.0	11.7	21.0	28.5	36.1	39.7	37.1	29.6	21.7	12.6	6.1	20.9
	MAX.	15.3	15.8	20.6	27.2	33.7	39.7	43.1	41.3	36.2	28.5	19.4	15.6	24.0
	YEAR	1954	1976	1974	1943	1941	1977	1940	1947	1940	1947	1970	1946	1940
	MIN.	-8.5	-5.8	-1.2	15.7	23.9	33.1	36.2	31.6	24.3	15.8	2.2	-3.0	17.0
	YEAR	1962	1973	1965	1968	1953	1951	1960	1950	1957	1952	1952	1952	1952
YEARS OF RECORD		39.	40.	40.	40.	41.	40.	41.	41.	40.	39.	40.	40.	36.
MONTHLY MEAN AVERAGE TEMP (F)	AVE.	15.5	18.0	24.4	35.2	44.7	53.3	58.8	56.3	48.8	39.3	25.3	18.6	36.5
	MAX.	25.3	26.7	32.8	43.0	48.6	58.7	61.5	59.4	53.0	44.3	34.6	27.2	38.9
	YEAR	1954	1954	1972	1943	1941	1977	1964	1947	1947	1950	1949	1950	1954
	MIN.	5.9	8.2	12.7	29.5	39.6	48.6	55.8	52.9	43.7	32.5	18.4	11.2	34.0
	YEAR	1962	1939	1965	1973	1953	1951	1950	1950	1961	1969	1952	1952	1952
YEARS OF RECORD		39.	40.	40.	40.	41.	40.	41.	41.	40.	39.	40.	40.	36.
DEGREE DAYS (BASE 65F)	AVE.	1528.0	1332.0	1269.1	908.2	634.0	343.2	193.7	278.5	501.0	812.0	1159.5	1473.1	10469.6
	MAX.	1827	1633	1619	1058	778	486	256	357	631	1003	1394	1662	11248
	YEAR	1962	1956	1965	1968	1953	1951	1958	1974	1961	1959	1952	1952	1952
	MIN.	1225	1058	990	754	519	184	106	170	392	669	999	1272	9428
	YEAR	1954	1954	1972	1954	1956	1977	1964	1969	1963	1963	1965	1977	1954
YEARS OF RECORD		27.	27.	27.	27.	28.	23.	28.	28.	27.	27.	27.	27.	26.
NO DAYS MAX TEMP GTR OR EQ 90F	AVE.	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	0.0	0.0	0.0	0.0	.1
	MAX.	0	0	0	0	0	0	1	1	0	0	0	0	1
	YEAR	1948	1948	1948	1948	1948	1948	1954	1973	1948	1948	1948	1948	1973
	MIN.	0	0	0	0	0	0	0	0	0	0	0	0	0
	YEAR	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978
YEARS OF RECORD		29.	29.	29.	29.	30.	30.	29.	30.	29.	29.	29.	29.	28.
NO DAYS MAX TEMP LESS OR EQ 32F	AVE.	20.8	14.8	9.7	1.5	.0	0.0	0.0	0.0	.0	.7	7.3	18.9	75.5
	MAX.	31	24	24	6	1	0	0	0	1	3	17	27	103
	YEAR	1962	1954	1965	1973	1967	1948	1948	1948	1971	1959	1948	1961	1952
	MIN.	11	5	0	0	0	0	0	0	0	0	0	4	48
	YEAR	1954	1954	1949	1978	1978	1978	1978	1978	1978	1978	1949	1950	1954
YEARS OF RECORD		30.	30.	30.	28.	30.	30.	30.	30.	29.	29.	30.	30.	27.
NO DAYS MIN TEMP LESS OR EQ 32F	AVE.	31.0	28.2	30.8	28.9	23.7	7.6	2.1	8.2	20.4	28.8	29.4	30.9	270.4
	MAX.	31	29	31	30	29	13	8	22	28	31	30	31	288
	YEAR	1978	1972	1976	1971	1972	1951	1963	1950	1957	1971	1978	1978	1950
	MIN.	30	28	28	24	14	1	0	1	12	22	26	29	246
	YEAR	1969	1978	1974	1959	1949	1948	1977	1961	1972	1972	1970	1955	1948
YEARS OF RECORD		30.	30.	30.	30.	30.	30.	31.	30.	30.	30.	30.	30.	28.
NO DAYS MIN TEMP LESS OR EQ 0 F	AVE.	12.5	10.5	6.0	.6	0.0	0.0	0.0	0.0	0.0	.3	4.6	10.4	46.0
	MAX.	23	20	16	3	0	0	0	0	0	2	11	18	60
	YEAR	1962	1954	1969	1973	1948	1948	1948	1948	1948	1975	1968	1966	1968
	MIN.	3	2	0	0	0	0	0	0	0	0	1	3	28
	YEAR	1954	1976	1978	1978	1978	1978	1978	1978	1978	1978	1970	1977	1972
YEARS OF RECORD		29.	30.	30.	30.	30.	30.	30.	30.	29.	29.	30.	30.	28.
HIGHEST TEMPERATURE (F)	TEMP	53	53	62	73	80	89	91	96	88	75	66	58	
	YEAR AND DAY	195021	195403	197830+	193929	196927+	195423	195412+	197304	197806+	196304+	195316	193910	
YEARS OF RECORD		39.	40.	40.	40.	41.	40.	40.	41.	40.	40.	39.	40.	
LOWEST TEMPERATURE (F)	TEMP	-48	-49	-34	-22	6	21	23	19	0	-12	-28	-39	
	YEAR AND DAY	196312	195101	195612	194504	194404	197001+	196801	197819	194219	197231	195010	196226	
YEARS OF RECORD		39.	40.	40.	40.	40.	39.	41.	40.	40.	39.	40.	40.	

Monthly Temperature Summary for Walden, Colorado, 1938-1978.

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SUMMARY OF MONTHLY CLIMATIC DATA FOR SPICER                COLORADO          LAST DATA  12/1978       SUBSTATION NO. 57848
PREPARED BY THE COLORADO CLIMATE CENTER,  DEPARTMENT OF ATMOSPHERIC SCIENCE,   COLORADO STATE UNIV.,    FT. COLLINS, CO 80523
                               LONGITUDE -   10628  LATITUDE -   4027  ELEVATION -   8380

                                          JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC     ANN

MONTHLY PRECIPITATION (IN)        AVE.   1.00     .91    1.13    1.36    1.30    1.14    1.37    1.53    1.16     .93     .94    1.16   13.96
                                  MAX.   3.49    2.44    3.30    3.42    3.20    4.02    3.12    3.39    4.37    2.95    2.15    4.82   17.96
                                  YEAR   1950    1962    1944    1935    1949    1949    1936    1963    1961    1947    1948    1948    1951
                                  MIN.   0.00     .12     .29    0.00    0.00    0.00    0.00     .07    0.00    0.00     .10     .29    8.73
                                  YEAR   1931    1931    1962    1954    1948    1958    1950    1944    1956    1952    1939    1975    1966
                       YEARS OF RECORD    45.     45.     45.     45.     45.     47.     47.     47.     47.     46.     45.     45.     44.

GREATEST DAILY PRECIP (IN)      AMOUNT   1.60     .30     .80    1.90    1.08    1.20    1.10    1.00     .90     .97    1.00    1.25
                          YEAR AND DAY195024  195709  194810  195323  197621  195713  195527  194923  197107  197707  195306  194822
                       YEARS OF RECORD    28.     28.     26.     28.     26.     29.     30.     28.     27.     26.     26.     22.

MONTHLY SNOWFALL   (IN)           AVE.   18.7    18.0    22.1    16.9     5.4      .2     0.0     0.0     1.5     5.0    15.6    22.3   109.9
                                  MAX.   73.0    74.0    78.0    44.0    29.0     5.0     0.0     0.0    34.0    23.0    59.0    85.0   214.0
                                  YEAR   1965    1952    1965    1973    1950    1976    1931    1931    1961    1966    1973    1973    1962
                                  MIN.    0.0     3.3     2.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0      .5     6.0    55.8
                                  YEAR   1931    1970    1947    1954    1974    1978    1978    1978    1977    1977    1949    1953    1931
                       YEARS OF RECORD    38.     41.     38.     38.     40.     45.     47.     46.     44.     39.     38.     33.     21.

GRTST DEPTH SNOW ON GRND IN MON (IN)       45      45      48      33      16       0       0       0      12      18      24      49
                          YEAR AND DAY195207+195229  196528+195506  195005       0       0       0 196123+196918  197304+194822
                       YEARS OF RECORD    23.     23.     19.     19.     18.     27.     30.     29.     29.     25.     25.     19.

NO DAYS PRECIP GTR OR EQ 0.1 IN   AVE.    4.1     3.2     4.2     4.0     4.8     4.2     4.8     5.5     3.9     2.8     3.5     4.3    50.5
                                  MAX.      8      11       8      12      13      10      10      14      12       9       9      10      66
                                  YEAR   1963    1952    1974    1952    1949    1962    1974    1963    1961    1972    1948    1948    1961
                                  MIN.      0       0       1       0       0       0       1       2       0       0       0       1      31
                                  YEAR   1977    1964    1966    1954    1948    1977    1972    1975    1956    1958    1969    1974    1966
                       YEARS OF RECORD    28.     28.     26.     27.     25.     28.     29.     28.     29.     26.     25.     26.     22.

NO DAYS PRECIP GTR OR EQ 0.5 IN   AVE.     .3      .3      .3      .3      .5      .8      .9      .9      .3      .4      .3      .5     4.7
                                  MAX.      2       3       5       2       5       7       4       3       3       2       5       7      29
                                  YEAR   1952    1949    1948    1951    1949    1949    1948    1955    1961    1972    1948    1948    1948
                                  MIN.      0       0       0       0       0       0       0       0       0       0       0       0       1
                                  YEAR   1978    1978    1978    1978    1978    1978    1976    1976    1978    1978    1978    1978    1976
                       YEARS OF RECORD    27.     27.     26.     27.     24.     28.     29.     27.     28.     25.     25.     23.     19.

NO DAYS PRECIP GTR OR EQ 1.0 IN   AVE.     .1     0.0     0.0      .1      .1      .1      .1      .0     0.0     0.0      .0      .1      .4
                                  MAX.      1       0       0       1       1       2       1       1       0       0       1       1       3
                                  YEAR   1950    1948    1948    1958    1977    1957    1977    1949    1948    1948    1953    1951    1948
                                  MIN.      0       0       0       0       0       0       0       0       0       0       0       0       0
                                  YEAR   1978    1978    1978    1978    1978    1978    1978    1978    1978    1978    1978    1978    1978
                       YEARS OF RECORD    29.     27.     26.     28.     27.     28.     29.     27.     29.     28.     26.     26.     22.

NUMBER OF DAYS WITH HAIL          AVE.    0.0     0.0     0.0      .2      .5      .7      .8      .7      .4     0.0     2.1     0.0     5.6
                                  MAX.      0       0       0       2       4       5       4       4       4       0      24       0      25
                                  YEAR   1955    1956    1956    1977    1961    1962    1957    1963    1970    1956    1968    1956    1968
                                  MIN.      0       0       0       0       0       0       0       0       0       0       0       0       0
                                  YEAR   1978    1978    1978    1978    1978    1978    1978    1976    1978    1978    1978    1978    1974
                       YEARS OF RECORD    21.     21.     21.     21.     22.     22.     22.     21.     22.     22.     19.     20.     18.

NO. OF DAYS WITH SNOW ON GROUND   AVE.   31.0    26.6    28.9    13.5      .9     0.0     0.0     0.0      .5     1.9    15.5    28.9   150.5
(GTR OR EQ 1 INCH ON GROUND)      MAX.     31      29      31      30       7       0       0       0       7       6      30      31     175
                                  YEAR   1963    1976    1978    1975    1975    1963    1963    1963    1965    1973    1974    1978    1974
                                  MIN.     31       9      17       0       0       0       0       0       0       0       2      19     114
                                  YEAR   1978    1977    1966    1977    1976    1978    1978    1978    1977    1977    1963    1975    1966
                       YEARS OF RECORD    12.     12.     11.     13.     16.     16.     16.     16.     15.     14.     13.     11.      6.
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Monthly Precipitation Summary for Spicer, Colorado, 1931-1978.

SUMMARY OF MONTHLY CLIMATIC DATA FOR SPICER COLORADO LAST DATA 12/1978 SUBSTATION NO. 57848
PREPARED BY THE COLORADO CLIMATE CENTER, DEPARTMENT OF ATMOSPHERIC SCIENCE, COLORADO STATE UNIV., FT. COLLINS, CO 80523
LONGITUDE - 10628 LATITUDE - 4027 ELEVATION - 8380

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MONTHLY MEAN MAXIMUM TEMP (F)	AVE.	28.0	31.6	37.3	47.6	59.5	69.0	76.7	74.2	67.1	55.8	39.7	30.6	51.4
	MAX.	34.7	39.9	45.7	56.3	66.5	78.1	83.2	78.1	76.5	67.8	49.6	40.2	54.8
	YEAR	1956	1934	1972	1943	1934	1955	1954	1948	1948	1950	1939	1939	1954
	MIN.	17.6	23.4	27.8	41.4	50.0	61.9	71.8	68.8	56.5	42.8	30.2	22.8	48.7
	YEAR	1932	1956	1965	1973	1935	1951	1973	1968	1961	1969	1938	1978	1964
YEARS OF RECORD		44.	43.	44.	44.	43.	46.	46.	46.	46.	45.	42.	41.	36.
MONTHLY MEAN MINIMUM TEMP (F)	AVE.	5.8	7.5	12.3	21.5	29.5	35.5	40.6	38.8	31.7	23.6	13.7	7.9	22.4
	MAX.	17.0	18.0	22.9	28.1	36.7	41.2	44.8	43.1	37.0	30.4	22.8	17.3	26.3
	YEAR	1953	1934	1934	1954	1934	1931	1940	1963	1939	1947	1949	1933	1934
	MIN.	-6.4	-2.9	1.1	14.6	25.2	31.8	34.9	33.2	25.3	15.5	6.0	-3.5	19.0
	YEAR	1944	1954	1965	1975	1968	1951	1950	1950	1978	1976	1956	1978	1976
YEARS OF RECORD		44.	43.	44.	44.	43.	45.	46.	46.	46.	45.	42.	42.	37.
MONTHLY MEAN AVERAGE TEMP (F)	AVE.	16.9	19.6	24.8	34.6	44.5	52.2	58.7	56.5	49.4	39.8	25.7	19.2	36.9
	MAX.	25.7	29.0	33.6	41.6	51.6	57.7	62.8	59.8	54.2	49.1	36.2	27.7	40.1
	YEAR	1953	1934	1934	1943	1934	1956	1954	1937	1948	1950	1949	1933	1934
	MIN.	7.8	10.7	14.5	28.9	38.8	46.9	55.6	53.1	42.9	31.1	18.3	9.7	34.3
	YEAR	1937	1954	1965	1975	1933	1951	1950	1978	1961	1969	1938	1978	1964
YEARS OF RECORD		44.	43.	44.	44.	43.	45.	46.	46.	46.	45.	42.	41.	36.
DEGREE DAYS (BASE 65F)	AVE.	1462.2	1281.6	1263.8	932.7	627.6	380.7	205.2	279.5	480.1	789.5	1145.1	1448.3	10336.6
	MAX.	1566	1559	1564	1078	755	536	276	362	655	1045	1310	1713	11121
	YEAR	1962	1954	1965	1970	1968	1951	1978	1978	1961	1959	1972	1978	1964
	MIN.	1210	1047	985	713	482	215	74	197	335	596	979	1228	9069
	YEAR	1953	1954	1972	1954	1958	1956	1954	1969	1954	1963	1963	1955	1954
YEARS OF RECORD		26.	25.	26.	26.	26.	25.	26.	26.	27.	25.	24.	24.	22.
NO DAYS MAX TEMP GTR OR EQ 90F	AVE.	0.0	0.0	0.0	0.0	0.0	0.0	.1	.0	0.0	0.0	0.0	0.0	.2
	MAX.	0	0	0	0	0	0	2	1	0	0	0	0	2
	YEAR	1948	1948	1948	1948	1948	1948	1954	1963	1948	1948	1948	1948	1954
	MIN.	0	0	0	0	0	0	0	0	0	0	0	0	0
	YEAR	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978
YEARS OF RECORD		28.	27.	28.	28.	28.	28.	28.	28.	29.	28.	26.	26.	24.
NO DAYS MAX TEMP LESS OR EQ 32F	AVE.	19.9	14.1	9.7	1.4	.0	0.0	0.0	0.0	0.0	.7	6.8	18.4	72.4
	MAX.	29	26	23	6	1	0	0	0	0	3	18	26	105
	YEAR	1949	1964	1965	1973	1950	1948	1948	1948	1948	1970	1948	1978	1964
	MIN.	7	4	3	0	0	0	0	0	0	0	0	4	51
	YEAR	1956	1954	1967	1978	1978	1978	1978	1978	1978	1978	1949	1950	1954
YEARS OF RECORD		29.	25.	28.	28.	29.	28.	28.	28.	29.	28.	26.	27.	20.
NO DAYS MIN TEMP LESS OR EQ 32F	AVE.	31.0	28.1	30.7	28.4	21.6	8.9	2.0	5.0	17.0	28.3	29.6	30.8	259.6
	MAX.	31	29	31	30	30	16	7	14	25	31	30	31	298
	YEAR	1948	1976	1978	1978	1971	1978	1978	1978	1957	1978	1978	1978	1978
	MIN.	31	26	27	21	13	2	0	0	5	19	27	30	229
	YEAR	1978	1952	1974	1954	1958	1953	1965	1970	1954	1972	1949	1971	1954
YEARS OF RECORD		29.	28.	29.	29.	28.	29.	29.	28.	24.	28.	26.	27.	16.
NO DAYS MIN TEMP LESS OR EQ 0 F	AVE.	9.4	8.0	5.2	.7	0.0	0.0	0.0	0.0	0.0	.4	3.8	8.5	35.9
	MAX.	20	17	14	4	0	0	0	0	0	2	10	16	51
	YEAR	1949	1964	1965	1973	1948	1948	1948	1948	1948	1948	1956	1978	1964
	MIN.	2	0	0	0	0	0	0	0	0	0	0	3	24
	YEAR	1953	1958	1974	1978	1978	1978	1978	1978	1978	1978	1965	1977	1954
YEARS OF RECORD		29.	27.	29.	29.	28.	28.	28.	28.	29.	28.	25.	26.	20.
HIGHEST TEMPERATURE (F)	TEMP	48	54	67	73	87	87	91	86	90	78	67	58	
	YEAR AND DAY	195022+	194029	193219	193213	194228	196127+	195413+	196926+	194702	194912	194903	193910	
YEARS OF RECORD		44.	42.	44.	44.	43.	45.	46.	46.	45.	46.	41.	40.	
LOWEST TEMPERATURE (F)	TEMP	-48	-36	-36	-19	1	11	19	20	4	-12	-32	-43	
	YEAR AND DAY	196312	193305	193211	193311	197001	194515	195508	196422	197820+	197231+	197628	197808	
YEARS OF RECORD		44.	43.	43.	44.	42.	46.	46.	46.	46.	45.	41.	42.	

Monthly Temperature Summary for Spicer, Colorado, 1931-1978.

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